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THE EFFECT OF CERTAIN CHEMICAL AGENTS UPON THE TRANSPIRATION AND GROWTH OF WHEAT SEEDLINGS

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(WITH NINE FIGURES)

The physiological factors involved in transpiration present numerous opportunities for critical study. A vast number of researches upon these factors have been made and our knowledge has been increased thereby; nevertheless the results of some important pieces of work are contradicted by others and more data seem to be necessary to elucidate certain questions.

The present paper is intended to set forth some data upon the effect of certain chemical compounds (mostly salts) upon the transpiration of wheat plants in relation to the effect of the same compounds upon the growth of the plants. In other words, the paper is in part a study of the effect of these compounds upon the units of water transpired for unit of plant substance produced.

The general literature bearing upon the effect of chemicals upon transpiration has been so well brought together and summarized by BURGERSTEIN (**2**) that a general review of literature need not be given at this place. A few studies which have especial bearing upon the present work, however, will be mentioned.

LAWES (**6**) made a careful investigation of the amount of water required by several plants grown to maturity, where possible, in sealed pots of soil. He used in one series soil to which no application of fertilizing compounds was added; in the second series a mineral fertilizer consisting of potassium sulfate, magnesium sulfate, sodium chlorid, and mono-calcium phosphate was added to the soil; in the third series the mineral fertilizer used in the second series was

supplemented with ammonium chlorid. In each series wheat, barley, beans, peas, and clover were grown. The third series having the ammonium chlorid failed to make satisfactory growth, but the other two yielded data of interest.

The application of the mineral fertilizer to soil in which wheat was grown diminished the amount of water required for the production of a unit of dry matter, and the mineral plus ammoniacal fertilizer diminished the amount still farther. The same relations held in the case of peas and clover. On the contrary, the amount of water transpired per unit of dry matter in beans was somewhat increased where the mineral fertilizer was present, and the same was true to a rather small extent in the case of barley, but only when the mineral fertilizer plus ammonium chlorid was present.

The experiments of SACHS (12), which have become classical, consisted in adding pure chemicals to sand, earth, or solution in which a plant was growing, and carefully observing the effect on the transpiration for a few days. In some experiments the supply of water in the soil was replenished after a few days, in others it was not. It was observed that the addition of KNO_3, $(NH_4)_2SO_4$, or gypsum to the soil decreased the amount of transpiration compared with that of a similar plant in control soil. Similarly, the addition of NaCl or $(NH_4)_2SO_4$ to distilled water decreased transpiration. A small amount of HNO_3 added to distilled water caused a great increase in transpiration, but a small amount of KOH caused retardation.

The investigations of BURGERSTEIN (1) confirmed the statements of SACHS and others in finding that acids accelerate transpiration and alkalies retard it. Solutions of calcium nitrate, potassium nitrate, potassium phosphate, potassium carbonate, ammonium nitrate, ammonium sulfate, magnesium sulfate, and sodium chlorid were tried, and all found to increase transpiration up to a certain point.

The observations of MAERCKER (10) upon the effects of potash fertilizers showed that the application of substances like kainit and carnallit has an effect upon the water requirement of white mustard. In his experiments the plants were grown in an artificial soil in large zinc pots. The soil, which consisted of sand containing 2.5 per cent. of peat, received the raw potash salts at the rate of 1000 and

2000^{kg} per hectare. In one set of experiments the soil received 60 per cent. of its capacity, and in another set 27 per cent. The effect of these treatments was found to be as follows:

Soil containing 60 per cent. of its water capacity. Treatment	Relative amounts of water required to produce one unit of dry weight	Soil containing 27 per cent. of its water capacity. Treatment	Relative amounts of water required to produce one unit of dry weight
No potash salts.....	100.0	No potash salts.....	100.0
1000^{kg} kainit per hectare...	90.5	1000^{kg} kainit per hectare...	77.1
2000^{kg} kainit per hectare...	88.4	2000^{kg} carnallit per hectare.	68.9
2000^{kg} carnallit per hectare.	91.9		

The economizing influence of the potash salts naturally showed itself more strongly upon the soil which contained the smaller proportion of water.

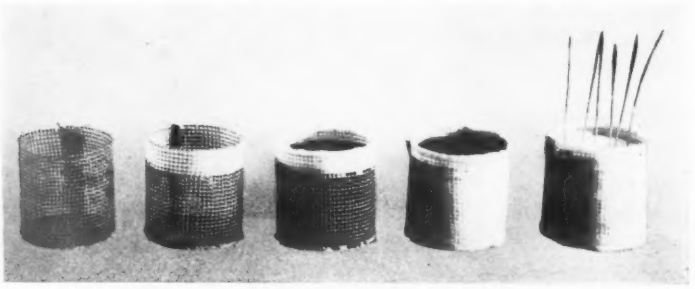
The pots in MAERCKER's experiments were not sealed to prevent loss of water from the surface of the soil; his figures therefore represent the total amount of water evaporated from the soil directly and through the activity of the plants, but they show very distinctly a tendency toward economy in water absorption where the potassium salts were applied.

HARTWELL, WHEELER, and PEMBER (**5**) have also reported that the application of potassium chlorid to wheat seedlings in soil causes an increase in green weight relatively larger than the increase in transpiration. In nutrient solutions it was found that sodium usually had a similar effect in retarding transpiration in comparison with growth.

GARDNER (**3**) has reported results which also show that the general effects of fertilizers applied to soils in pots was to increase in various ratios the amount of green weight in proportion to the water transpired.

SORAUER (**15**) and HARTER (**4**) have reported the results of experiments in which a large amount of soluble salt was added to soil or solution and the effect upon transpiration noted. The large amounts of salts which they employed produced halophytic conditions with corresponding changes in the anatomy of the plants, therefore their results will not be compared with those which follow in this paper, because in them the amounts of salt added were not sufficient to alter materially the concentration of the soil solution.

The data to be presented in this paper were drawn from upward of 6000 tests employing soils, soil extracts, and salt solutions. The data showing the effects of treatments upon soils were obtained from experiments which employed 189 soils from various parts of the United States. These data were obtained in the course of fertility tests made by the Bureau of Soils of the U. S. Department of Agriculture, and were kindly furnished by Mr. F. D. GARDNER, who was in charge of the work; the other data are drawn from



a *b* *c* *d* *e*

FIG. 1.—Method of making paraffined wire pots: *a*, wire frame; *b*, same with rim of paraffin; *c*, same filled with soil; *d*, completed pot, having wall formed by repeated dipping in melted paraffin; *e*, pot containing plants four days old and showing the cover of paraffined paper sealed to rim of the pot.

experiments made by the author while a member of the staff of that bureau's laboratory.[1]

All tests conducted with soils were made in the standard paraffin wire pot employed extensively for experimental work in plant physiology and agronomy. As an instrument of research it commends itself especially because of its easy construction and its ability to yield accurate experimental results.[2]

The method of making these pots is illustrated by *fig. 1*. The framework of wire netting is 10^{cm} in diameter and of the same height (*a*). After coating the rim of the framework by dipping several

[1] For making most of the computations upon which this paper is based, I am indebted to my wife, HANNAH D. REED.

[2] This method finds commendatory mention in GANONG's *Plant physiology*, 2d ed., 1908, p. 173.

times in melted paraffin (*b*), the pot is filled slightly above the edge of the paraffined rim with soil which has received enough water to place it in optimum condition (*c*). The pot is then dipped in melted paraffin with intermediate cooling until a firm wall is formed (*d*). At the first dipping the paraffin penetrates a short distance into the soil and thus cements the outer surface of the mass of soil to the wall of the pot. A straight, shallow furrow is then made across the surface of the soil and the seeds planted in it. In the present work, where wheat was used, it was previously soaked in tap water until undoubted signs of germination were shown and seven seeds were planted in each pot. If seven plants appeared above the surface of the soil, one was subsequently removed, leaving six to grow in each pot. It is advisable to cover the surface of the soil in the pot with a layer of clean sand to prevent a crust from forming on the soil, as well as to aid in uniformly distributing the water which is added. The pots are carefully weighed on the day of planting, when the soil is in the optimum moisture condition, and their weight recorded. A few days after the plants appear above the surface of the soil, the pot is sealed by covering the top with a circular piece of paraffined paper provided with a narrow slit in a position which allows the row of plants to pass. The paper is sealed to the inner surface of the wall of the pot with paraffin. Such a pot is shown at *e* in *fig. 1*. The pot is weighed immediately before and after sealing, and the increase of weight due to the addition of paper and paraffin is added to the initial weight recorded as the "optimum" for each pot. The paraffined paper prevents the loss of all but a very slight amount of moisture by evaporation from the soil. Since it is transpiration relative to control cultures and not absolute transpiration which was determined, the small amount of water lost through the slit may be neglected. Thereafter distilled water is added in sufficient quantity at intervals of three or four days to keep the weight of the pots near that of the original. When water was required by the pots, it was introduced through the slit in the paraffined paper cover by means of a pipette.

One of the conspicuous points of superiority which the paraffined wire pot possesses over the ordinary pot with a non-adhesive wall is shown in *fig. 2*. In experiments of this character, where the effect

of soil treatment is to be estimated by the result upon plant growth, it is essential that the roots of the test plants be living within the soil instead of being external to it. *Fig. 2* shows at the left the soil mass from a paraffined wire pot, and at the right that from a pot with a non-adhesive wall. Wheat plants had grown in each pot for three weeks at the time the photograph was made. In the paraffined pot the plant roots were entirely restricted to the soil mass, while in the other pot the absorbing region of a majority of the roots was external to the soil and hence not indicating response to the treatment given to that soil.

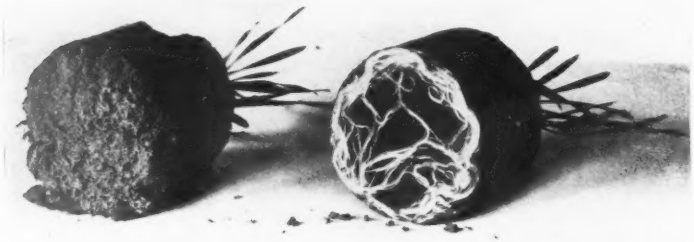


FIG. 2.—Root distribution in paraffined wire pot and in ordinary pot; on the left is shown the contents of a paraffined wire pot, and on the right those of an ordinary pot.

During the course of an experiment the pots were kept in situations where the conditions of heat and light were as nearly uniform as possible.

The exact duration of the different experiments naturally varied somewhat on account of external factors, but was usually 18 to 21 days. During very hot summer weather the period was often somewhat shortened; the best conditions for growth in Washington, D. C., being found in the months of May and September. In order to eliminate errors which might unavoidably arise, as well as inherent differences in individual plants, five pots, each containing six seedlings, were used for each test; therefore, in recording the effect of any treatment, the total transpiration and green weight of the 30 plants distributed in five pots were taken. The total transpiration was determined by summing up the total losses of water from the pots dur-

ing the experiment; the green weight was found by cutting the plants at the surface of the soil in the pot and weighing them immediately, before any material loss of water occurred. If the dry weight was to be recorded, the plants from each set of pots were placed in unsealed paper envelopes and slowly dried at room temperature.

Many experiments described in this paper were carried out in water cultures, in which the aqueous extract of a soil, or a salt solution was used as the culture fluid. The water cultures were prepared and conducted according to the methods described by LIVINGSTON (**8**) and SCHREINER and REED (**14**), in which 10 wheat seedlings are installed in each culture jar. The culture jars employed in this work were saltmouth green flint glass bottles of 240^{cc} capacity. Flat corks which fitted the mouths of these bottles were notched by cutting ten vertical wedges from their lateral surface. Each wedge was about 4^{mm} broad and 5 or 6^{mm} deep, and extended from top to bottom of the stopper. The cork wedges, after being cut out, were truncated at their inner angles by the removal of enough cork to allow them to be replaced in position after a seedling had been placed in the inner apex of the space from which each wedge had been cut. The stem of the seedling was placed in its groove, with the seeds just below the lower surface of the cork, and the wedges were pressed into position. Each wedge should exert sufficient pressure on the seedling to hold it in place when the stopper is inserted in the bottle. After all were in position, a rubber band was placed around the stopper to hold the wedges in place, and the stopper was then pressed firmly into the neck of the bottle which contained the culture fluid. The cultures prepared by this method afford practically no opportunity for the direct evaporation of water from the bottles. Practically all the water lost occurs as transpiration from the plants grown in the cultures. To keep conditions equable, the solution in the bottles should be renewed or the bottles replenished with distilled water every four or five days.

Since the water loss is only through the plants, the cultures may be weighed at each change, and the sum of the losses recorded may be taken as the total transpiration of the 10 plants for the period of the experiment. This total water loss being proportional to the leaf area when wheat is used, it is consequently a practical method for

comparing growth of several cultures when grown simultaneously under the same conditions.

It seems not improper to point out that, under these conditions of experiment, the water content of the medium in which the plants were grown was very nearly constant during the period of the experiment, a condition which has been lacking in many experiments upon transpiration. SACHS, for example, supplied water to the soil at the beginning of an experiment, but usually added no additional water during the course of the experiment.

Most of the studies recorded in this paper are based upon the amount of water transpired per gram of green substance produced under different conditions of experimentation, a factor which in the present study is designated "correlative transpiration."

In most of the experiments involving the use of soil, four different chemical compounds were used, viz., nitrogen as sodium nitrate, potassium as potassium sulfate, phosphorus as mono-calcium phosphate, and calcium as calcium carbonate. The first three salts were applied to the soils, where used, at the rate of 100 parts to a million of soil, but calcium carbonate was added at the rate of 1000 parts per million of soil. To facilitate accuracy and rapidity, the first three salts were applied in the form of solutions, but the calcium carbonate was added in a dry, finely ground condition.

A general survey of the data presented in the following pages shows that, in the majority of cases, the plant growth was increased by the addition of various compounds commonly used as fertilizers in agricultural practice. The paper by GARDNER (3) contains extensive data upon this point, all of which were obtained by the use of the paraffined wire pot. GARDNER'S data are consonant in showing an increase in plant growth. Some of the soils employed were what might be termed unproductive soils; their unproductiveness, however, was in some cases due rather to the presence in them of deleterious compounds than to actual poverty in nutrient substances. Others of the soils he employed were productive. Naturally the increases due to the addition of fertilizer compounds were greater in the former class of soils.

The studies under consideration in this paper relate to the transpiration correlated with growth as affected by the addition of

definite chemical agents to the soil or solution in which the plants were grown.

Experimental results

STUDIES ON THE TRANSPIRATION OF PLANTS GROWN IN SOILS

The first data presented deal with the average effect of the four different salts upon the transpiration of plants grown in 189 soils from different localities.

The untreated pots used as controls exhibited an average transpiration of 103.3^g water for each gram of green weight produced. In the pots where the salts were added the amounts of water transpired per gram of green weight were: $NaNO_3$, 93.36^g; K_2SO_4, 97.95^g; $CaH_4(PO_4)_2$, 104.07^g; $CaCO_3$, 101.09^g. Using the transpiration of the controls as a basis and representing it as 100, the different treatments would have the following values: $NaNO_3$, 90.40 per cent.; K_2SO_4, 94.80 per cent.; $CaH_4(PO_4)_2$, 100.8 per cent.; $CaCO_3$, 97.9 per cent.

These figures show that at least two of the four salts employed were responsible for a proportionally diminished transpiration. In the case of the other two, the differences from the control were not so great, in fact in the case of mono-calcium phosphate the units of water used were almost precisely the same as in the controls. It may be said in passing that in individual cases the economy of water used was much greater than would appear from the average result. For example, one sample of Crawford clay, to which $NaNO_3$ was added, showed only 69 per cent. as many units of water required for a unit of growth as in the untreated soil, at the same time growth was increased 31 per cent. Also, in a sample of Portsmouth swamp soil, to which K_2SO_4 was added, the units of water required for a unit of growth were only 71.2 per cent. of what was required in the controls, while growth was increased 112 per cent.[3]

Since the introduction of extraordinarily low figures brought down the average figures, I next made an investigation of the amounts of

[3] In this connection it may be said that the opposite relation was sometimes observed, namely, an increased consumption of water when growth was diminished by the addition of a salt. In a sample of Memphis silt loam, to which K_2SO_4 was added, the resulting growth was but 91 per cent. of that in untreated soil, while the water required per unit of growth was 17 per cent. more than in the controls.

water transpired in experiments where the salts had a slight influence upon growth and also in experiments where influence was large. I selected for this purpose two classes of results, in one of which the effect of the added salt upon the green weight of the plants was so small as to be doubtful, and in the other there was a distinct acceleration. In the first class of results the response as measured by green weight varied between 95 and 105, and is regarded as doubtful response, since a variation of only 5 per cent. above or below the controls may be regarded as within the limit of error. In the other class of results the response was 120 or greater, and therefore includes cases in which there was undoubted acceleration.

A summary of the results of these tests is presented in table I. Each computation is the average of 25 tests, with the exception of no. 1, which is the average of 20 tests.

TABLE I

EFFECT OF VARIOUS SALTS UPON TRANSPIRATION OF WHEAT PLANTS IN CASES WHERE THE CORRELATED EFFECT UPON THE GROWTH WAS VERY SMALL AND IN CASES WHERE IT WAS DISTINCTLY INCREASED. SALTS ADDED TO SOIL IN WHICH PLANTS GREW

No.	Salts added	Green weight of plants grown in soils receiving the salt. Controls = 100 in each case	Units of water transpired per unit of green weight. Controls = 100 in each case
1	$NaNO_3$	100.25	95.3
2	"	130.00	84.0
3	K_2SO_4	101.00	94.0
4	"	128.00	86.0
5	$CaH_4(PO_4)_2$	100.16	100.4
6	"	128.00	95.5
7	$CaCO_3$	100.5	99.9
8	"	142.0	99.0

These results may be regarded as giving added light to those previously presented. They show that in the case of $NaNO_3$ and K_2SO_4 there was greater economy of water used the greater the effect upon growth as indicated by the green weight. In the case of $CaH_4(PO_4)_2$ and $CaCO_3$, it has already been shown that their inhibiting effect upon transpiration is much inferior to that of $NaNO_3$

and K_2SO_4. In the case of $CaH_4(PO_4)_2$, as shown in table I, there is, however, a slight decrease in the units of water required for a unit of green weight where the growth response was greater. In the case of $CaCO_3$ the difference is too slight to warrant any statement one way or the other.

The relations between green weight and transpiration are further illustrated by the graphic representation given in *figs.* 3, 4, and 5. To construct the curves there shown I selected from each set of experi-

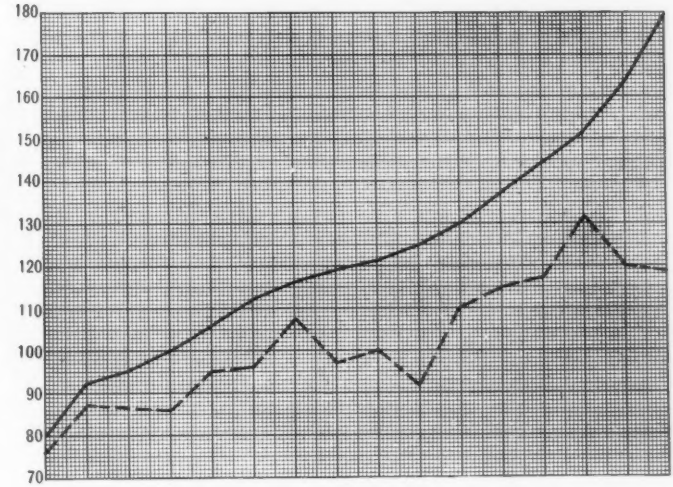


FIG. 3.—Correlative growth and transpiration in soils to which K_2SO_4 was added; in all charts the continuous line represents green weight, and the broken line transpiration.

mental data an ascending series of green weights. These figures ranged, as shown, from a value slightly less than that of the controls to a value indicating a growth approximately twice as great as that of the controls. The control for each one is represented by 100, therefore the position of the points above or below 100 on the chart represents the effect of the salt which was added to the soil in that particular series of experiments.

Arranging the figures representing the green weights in an ascending order, I let the respective transpiration figures fall as they might.

The transpiration was estimated in each case by comparison with the transpiration of the control plants, the transpiration controls being also represented as 100. By joining these points, a curve was obtained representing the rise and fall of the transpiration in comparison with the somewhat steady rise of the green weight in these selected cases. In all charts green weight is represented by the continuous line and transpiration by the broken line.

In selecting these figures, care was taken to omit all in which the results might appear to be large on account of very small growth in

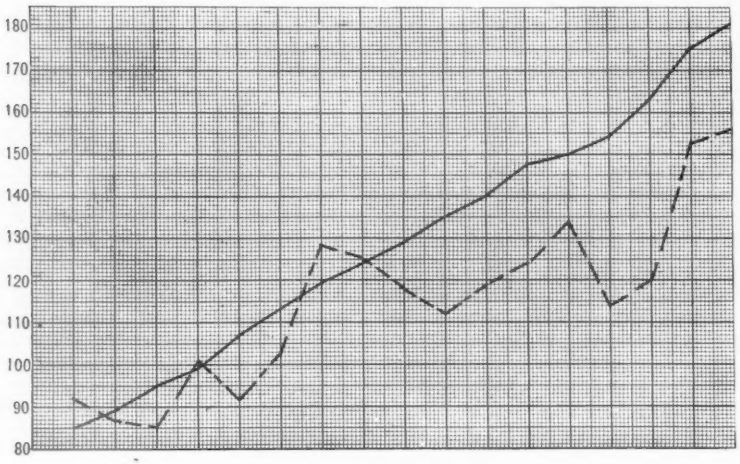


FIG. 4.—Correlative growth and transpiration in soils to which $NaNO_3$ was added.

the control. Had such been included the results would have been even more striking than they stand.

An inspection of *fig. 3* shows that potassium sulfate in particular acts as an economizing factor (agent) in transpiration. In this case the curve representing the transpiration of the plants lies entirely beneath the green weight curve. The transpiration curve rises as the green weight curve rises but the rise is not exactly parallel. This fact harmonizes with the relation brought out in a preceding paragraph dealing with the relative quantities of water required where the corresponding increase in green weight was small and where it was

large. In the lower part of the figure, where the green weight is near 100, the two curves lie closer together and more nearly parallel than in the upper part of the figure. From these relations it appears that the transpiration per unit of green weight is smallest when the acceleration of growth caused by the application of K_2SO_4 was greatest.

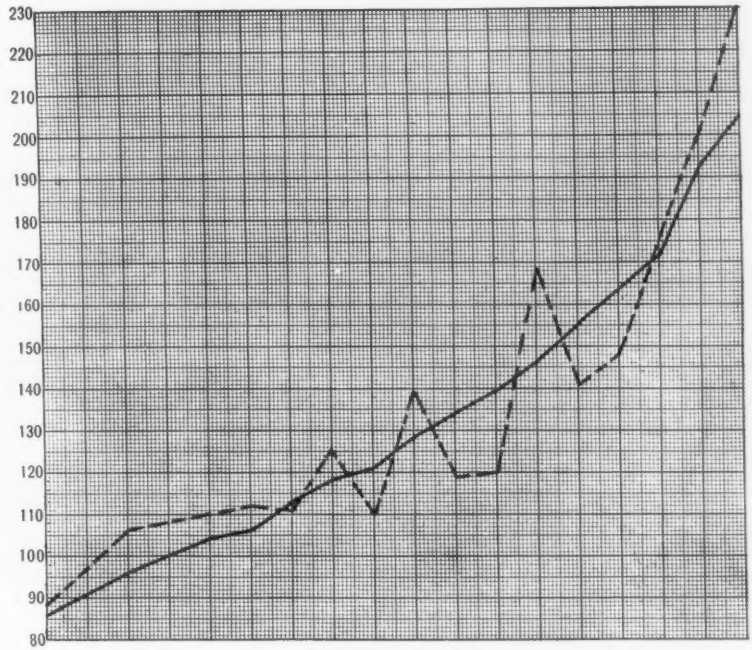


FIG. 5.—Correlative growth and transpiration in soils to which $CaCO_3$ was added.

Fig. 4 shows curves constructed in a similar way to show the action of sodium nitrate upon green weight and transpiration. As before, the numerical values representing the green weight of the various experimental plants are arranged in an ascending series. The curve representing the transpiration of the plants is somewhat more irregular than in the case of the K_2SO_4 experiments, yet its mean position lies somewhat below the green weight curve. This is interpreted to mean that the transpiration of plants grown in pots

to which $NaNO_3$ was added was relatively less than the correlated green weight; in other words, that the influence of the $NaNO_3$ was to reduce the amount of water required per unit of green weight.

In the lower part of the figure the mean of the transpiration curve lies closer and more nearly parallel to the green weight curve than in the upper part. This relation is in harmony with the facts previously presented in showing that the economizing action of the $NaNO_3$ was greater where the greatest acceleration in growth was produced (compare table I).

Fig. 5 likewise represents similar relations between green weight and the transpiration in experiments where calcium carbonate was added to the soils. A brief inspection suffices to show that the mean curve of transpiration lies very close to the green weight curve. In the lower part of the figure the transpiration curve is slightly above that for green weight; however, the mean of the former curve approximates closely that of the green weight.

Contrary to the relations exhibited by the two preceding pairs of graphs, the transpiration curve does not perceptibly diverge from the green weight curve in the upper part of its course; thus showing that increased growth due to the action of this salt was not correlated with a reduction of water transpired per unit of green weight produced. This relation is corroborated by the results presented in table I, where the units of water transpired per unit of green weight were scarcely different in cases of low response and high response.

STUDIES ON THE GROWTH AND TRANSPIRATION OF PLANTS GROWN IN SOIL EXTRACTS AND SOLUTION CULTURES

A comparative set of experiments was carried out by the use of aqueous soil extracts as a medium for plant growth. The extracts were made by stirring one part soil with five parts non-toxic distilled water. The mixture was stirred five minutes, allowed to stand thirty minutes, and then filtered through a Pasteur-Chamberland filter. This method gives a good, clear soil extract and is easily employed. Salts were added to the soil extracts and their effect upon transpiration observed as in the case of the pot experiments in which soil was used. As in the case of the former series of experiments, there was, on the aggregate, increased growth, resulting from the addition of salts

commonly used as fertilizers. A few cases in each series gave growth somewhat less than the controls and others were practically equal to the controls, but a goodly number in each series gave material responses in the positive direction. On account of a smaller number of experiments, not so many comparisons are possible, however, as in the case of the former series.

One feature associated with the growth of wheat plants in soil extracts or nutrient solutions is deserving of especial mention. When the compounds added to a medium caused (as many of them did) a material increase in root growth, there was usually a corresponding increase in transpiration, regardless of whether the growth of the green parts of the plants was greatly increased or not. It is held that the increase in size of the absorptive system is connected in some way with an accelerating action upon the escape of water from the subaerial portions of the plant.

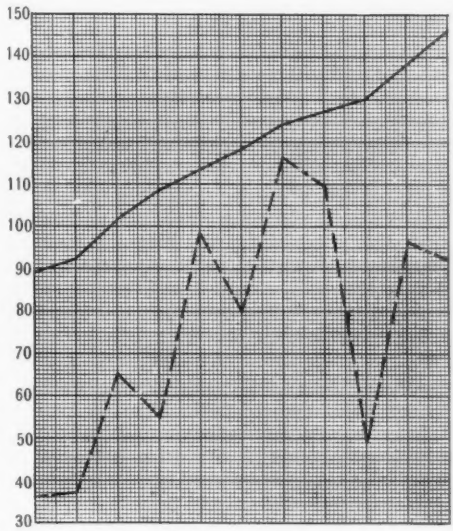


FIG. 6.—Correlative growth and transpiration in soil extracts to which K_2SO_4 was added.

The first computations are concerned with the units of water required to produce a unit of green weight, and the influence of various compounds thereupon.

The plants grown in soil extract to which sodium nitrate was added showed a transpiration per unit green growth 96.7 per cent. of transpiration in the controls. Similarly, the transpiration in soil extract plus potassium sulfate was 85.3 per cent.; in extracts plus

sodium phosphate, 110 per cent.; in extracts plus calcium carbonate (saturated solution), 163 per cent. of the controls.

In the former series of experiments there was no comparison between the sodium and the potassium salts of the same acid. A few comparisons were made in this series of experiments employing K_2SO_4 and Na_2SO_4, the results of which are of some interest, since one of the salts functions as a plant nutrient and the other probably does not. In the comparison at present under consideration it was

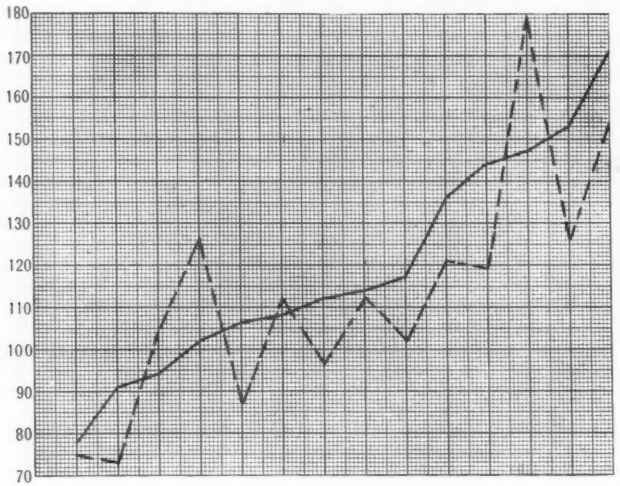


FIG. 7.—Correlative growth and transpiration in soil extracts to which $NaNO_3$ was added.

found that plants grown in soil extracts receiving sodium sulf te exhibited a transpiration per unit of green weight equal to 93.9 per cent. that of the controls, whereas an equivalent amount of potassium sulfate added to extracts of the same soils and in which plants were simultaneously grown gave 85.3 per cent.

A comparison of the effects of two different salts of potassium was afforded by the results from the use of potassium chlorid and potassium sulfate in extracts of the same soil. Sixteen experiments were selected in which these two salts had been added to extracts of the same soil, and plants grown simultaneously.

The average transpiration for unit of green weight was 56.77g in the controls, 34.81g for KCl, and 34.05g for K_2SO_4. Expressed in percentage of the controls, the addition of KCl caused a use of water amounting to 61.4 per cent. of the controls, and K_2SO_4 caused a use of water amounting to 60 per cent. of that used by the controls in untreated soil extract.

It appears, therefore, that potassium is more efficient than sodium in diminishing the transpiration per unit of green growth produced. Different salts of potassium did not exhibit wide variation in their inhibiting action upon transpiration. Sodium, however, is able, to some extent, to retard the transpiration per unit growth, and part of the retarding action of sodium nitrate is therefore attributable to the action of the sodium ion.

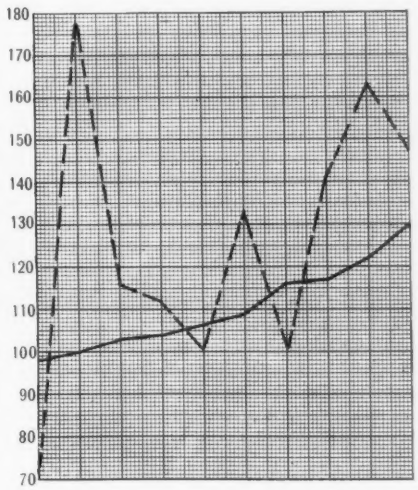


FIG. 8.—Correlative growth and transpiration in soil extracts to which Na_2HPO_4 was added.

The effect of adding these salts to soil extracts is shown by curves in *figs. 6, 7, 8,* and *9*, where the method of constructing the curves was similar to that used for *figs. 3, 4,* and *5*. In *fig. 6*, which shows the effect of K_2SO_4, it is evident that the correlative transpiration is much lower than the growth, since every point in this transpiration curve is below the green weight curve. The middle portion of the transpiration curve lies nearer the green weight curve than either of the extremities, but the general trend of this curve shows that constant retarding action upon transpiration in all cases whether the green weight of the plant was increased much or little.

The effect of $NaNO_3$, as shown in *fig. 7*, is not so marked in retarding transpiration. Here the mean of the transpiration curve

lies very close to the green weight curve, and is generally parallel to it. The upper part of the transpiration curve, which lies somewhat below the green weight curve, may probably be regarded as showing a retardation of transpiration in those examples.

Fig. 8, showing the relationship between green weight and transpiration in cultures to which Na_2HPO_4 was added, may be regarded as a general indication of the effect of the PO_4 ion. The transpiration here appears to be generally higher than the correlative green weight and is accordingly consonant with former results.

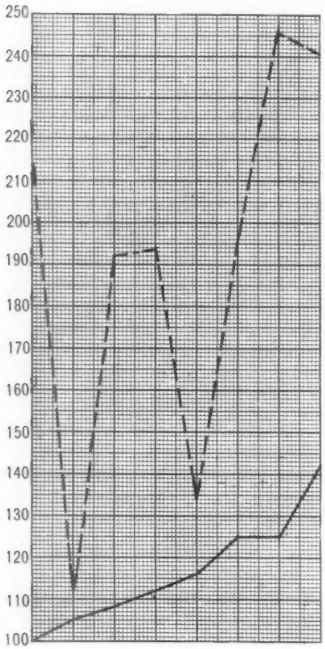


FIG. 9.—Correlative growth and transpiration in soil extracts to which $CaCO_3$ was added.

The effects of $CaCO_3$, as shown by the curves in *fig. 9*, is very accelerating upon transpiration. Although the transpiration curve is subject to somewhat extreme fluctuation, all its points lie above the green weight curve and the mean of the transpiration curve lies far above.

It may be said that, in the main, the salts had the same effect when added to soil extracts as when added to the soil in which plants were grown, although, in the case of $CaCO_3$ the results were somewhat more emphasized in the soil extracts.

The next studies taken up were devoted to the effect of acids and alkalies upon transpiration. This question has previously been studied by numerous investigators, notably SENEBIER, SACHS, and BURGERSTEIN, all of whom apparently agree in showing that the addition of a small amount of an acid increases the transpiration, while the addition of a small amount of alkali decreases transpiration.

In my experiments the acids or alkalies employed were added in smaller amounts than used by SACHS or BURGERSTEIN; and the experiments were extended for 12 to 15 days instead of 1 to 4 days, as in BURGERSTEIN'S experiments. The cultures were set up in duplicate with ten wheat plants to each culture.

In the two experiments first presented tests were made with organic and inorganic acids. The effect of these acids upon transpiration, green weight, and the correlation between the two is shown in tables II and III.

TABLE II

UNITS OF WATER TRANSPIRED PER UNIT OF GREEN WEIGHT IN WHEAT CULTURES CONTAINING VARIOUS AMOUNTS OF OXALIC AND ACETIC ACIDS

No.	Solution	Transpiration grams	Green weight grams	Units H_2O per unit green weight
1	Control in H_2O	64.5	1.47	43.8
2	$C_2H_2O_4$ $\frac{n}{2500}$	105.0	1.82	57.7
3	" $\frac{n}{5000}$	106.0	1.93	54.9
4	" $\frac{n}{10000}$	60.0	1.56	38.4
5	" $\frac{n}{20000}$	106.5	2.03	52.4
6	" $\frac{n}{40000}$	72.0	1.91	44.7
7	$CH_3 \cdot COOH$ $\frac{n}{2500}$	65.5	1.61	40.7
8	" $\frac{n}{5000}$	137.5	2.48	55.5
9	" $\frac{n}{10000}$	69.5	1.67	41.6
10	" $\frac{n}{20000}$	78.5	1.56	50.3
11	" $\frac{n}{40000}$	87.0	1.76	49.4

Several relations are indicated by the results presented in these tables. The figures indicate that the transpiration of the plants was slightly increased by the addition of small amounts of inorganic acids, and in most cases was perceptibly increased by the addition of the organic acids. The figures expressing the green weight show that the addition of acids generally increased the green weight, possibly excepting H_2SO_4 and the stronger solutions of HCl. This

relation is perhaps due to the fact that these solutions proved injurious to growth as indicated by transpiration and green weight. When one examines the figures showing the units of water transpired per unit of green weight, he finds that the presence of inorganic acids in the

TABLE III

UNITS OF WATER TRANSPIRED PER UNIT OF GREEN WEIGHT IN WHEAT CULTURES CONTAINING VARIOUS AMOUNTS OF INORGANIC ACID

No.	Solution	Transpiration grams	Green weight grams	Units H_2O per unit green weight
1	Control in H_2O	53.0	1.46	36.3
2	HCl $\frac{n}{2500}$	26.0	.90	28.8
3	" $\frac{n}{5000}$	27.5	1.08	25.4
4	" $\frac{n}{10000}$	32.5	1.50	21.7
5	" $\frac{n}{20000}$	52.0	1.75	29.1
6	" $\frac{n}{40000}$	57.2	1.73	33.0
7	HNO_3 $\frac{n}{2500}$	35.5	1.40	25.3
8	" $\frac{n}{5000}$	46.5	1.61	25.1
9	" $\frac{n}{10000}$	61.5	1.84	33.4
10	" $\frac{n}{20000}$	59.5	1.75	34.0
11	" $\frac{n}{40000}$	47.5	1.67	28.4
12	H_2SO_4 $\frac{n}{2500}$	15.5	1.24	12.5
13	" $\frac{n}{5000}$	32.0	1.19	26.9
14	" $\frac{n}{10000}$	49.5	1.60	30.9
15	" $\frac{n}{20000}$	45.0	1.46	30.8
16	" $\frac{n}{40000}$	30.0	1.38	21.7

concentrations there used did not cause an increase in the amount transpired per unit green growth, but caused instead a greater or less retardation in transpiration. In the experiments where organic acids were added the proportional transpiration, in most of the cases, was somewhat larger than that of control plants. Here then the results may be said to agree with those of the authors previously mentioned. But the results given in table III show quite general disagreement.

In attempting an explanation for these differences, attention may be directed first to the fact that the plants in my experiments were grown for longer periods of time in the acid solutions than those of the previous investigators, and the possibility exists that accelerated transpiration of these plants was temporary and would eventually have given place to a retardation. The plants upon which my observations were made had developed almost from germination in the solutions to be tested, since they were transferred to the solutions when the longest roots were 2–3^{cm} long.

The greatest reason for the apparent difference in results is believed to be due to the fact that the previous writers have taken no account of the correlated growth in measuring transpiration. Transpiration is probably a function of growth, and as such cannot be separated from it. It seems more correct, therefore, to estimate the effect of a treatment in terms of the transpiration per unit of green weight, or, since in my experiments the green weight was at the beginning of the experiment almost *nil*, to estimate the effect of the treatment in terms of the transpiration *per unit increase* in green weight.

THE ACTION OF ALKALIES

This problem was also studied by the earlier investigators in manner similar to that employed for studying the action of acids, which, as previously stated, is open to certain objections. The results of my experiments, which record the amount of transpiration per unit of green growth, disagree with those of the writers quoted. My experiments on this point were conducted upon wheat plants growing in water cultures, prepared by the methods previously described. The hydroxids of potassium and of sodium were present in these cultures in concentration of $n/100$; this involved the addition of 39 parts per million of K in the form of KOH, and 23 parts of Na as NaOH, amounts approximating those employed in the other experiments.

Table IV presents the average result of two experiments in which KOH and NaOH were added to extract of Hagerstown loam, a sample which was known to "respond" to potash fertilizers being used.

Unfortunately, the number of my observations is small, and it

would be unsafe, therefore, to make any extended discussion of the results, although they are believed to be entirely consonant with the true state of affairs. So far as they go, they disagree with those of

TABLE IV

PLANTS EFFECT OF KOH AND NaOH UPON GROWTH AND TRANSPIRATION OF IN EXTRACT OF HAGERSTOWN LOAM. AVERAGE OF TWO EXPERIMENTS

No.	Solution	Transpiration	Green weight	Units water transpired per unit green weight
1	Untreated soil ext.	100	100	26.9
2	Soil ext. plus $\frac{n}{100}$ KOH	182	160	30.5
3	Soil ext. plus $\frac{n}{100}$ NaOH	157	138	29.2

previous workers in showing that both the absolute and the relative amount of transpiration was increased by the addition of KOH and NaOH in small amounts. In these small amounts the effect upon growth appears to be distinctly beneficial. The transpiration per unit of green growth appears to have been increased slightly where the hydroxids were added.

The effects of pyrogallol and tannic acid were studied on plants grown in soil extracts. The addition to the extract of a soil, especially if it be an unproductive soil, of these substances which probably possess no nutrient value usually causes increased growth and greatly increased transpiration. The effects of small amounts of these substances is shown in table V, where the figures are the average of six experiments on soil taken from six different plots at one of the state agricultural experiment stations.

TABLE V

EFFECT OF PYROGALLOL AND TANNIC ACID ON SOIL EXTRACT. AVERAGE OF SIX EXPERIMENTS

No.	Solution	Transpiration	Green weight	Units water transpired per unit of green weight
1	Control	100	100	100
2	Soil ext. plus 5 parts per million pyrogallol	160	109	139
3	Soil ext. plus 5 parts per million tannic acid	139	100	133

From these results it would appear that the pyrogallol and tannic were responsible for very marked increases in transpiration, without causing correspondingly marked increase in green weight, in fact the average effect of tannic acid shows no increase in green weight. Where the action of these compounds upon soil extracts has been studied, they have been found to accelerate principally two things, transpiration and root growth. In this respect their effect resembles that of manure extract, as has been pointed out by SCHREINER and REED (**13**). From a rather extended study of this phenomenon under various conditions, it seems only logical to conclude that pyrogallol

TABLE VI

EFFECT OF PYROGALLOL UPON ROOT GROWTH, TOP GROWTH, AND TRANSPIRATION IN TWO SOIL EXTRACTS

No.	Solution	Transpiration	Weight of entire plant	Weight of tops	Weight of roots*	Units water transpired per unit green weight
1	Extract of soil "A"	100	100	100	100	100
2	Same plus 2 p.p.m. pyrogallol	100	94	88	100	113
3	Same plus 4 p.p.m. pyrogallol	122	114	85	146	144
4	Same plus 8 p.p.m. pyrogallol	76	117	81	156	94
5	Extract of soil "B"	100	100	100	100	100
6	Same plus 2 p.p.m. pyrogallol	119	98	95	104	125
7	Same plus 4 p.p.m. pyrogallol	138	116	99	143	140
8	Same plus 8 p.p.m. pyrogallol	152	132	106	171	143

* The roots were taken from the solution, quickly dried between sheets of filter paper, and weighed. A small amount of capillary water was present, but the error is minimized by the fact that the figures given are comparative, not absolute.

in a soil extract acts to improve the conditions for growth by acting upon deleterious organic compounds present in those extracts. In non-toxic distilled water, similar effects are not observed. The improvement in growth conditions which follows the action of pyrogallol and other phenol derivatives is more quickly and markedly manifested by the roots than by the green parts of the plant (cf. the illustrations reproduced in the last-named publication). This point is well illustrated by an experiment whose results are presented in table VI. In this experiment pyrogallol was added at the rate of 2, 4, and 8 parts per million to extracts of two soils taken from the experiment grounds of an experiment station. Soil "A" was taken from a rich cabbage field; soil "B" was taken from an unproduc-

tive timothy meadow. In estimating the results the weight of the roots and tops was separately taken.

These results show (with the exception of no. 4) a good correlation between transpiration and root growth. The order of responses is the same in the respective columns. In the case of no. 2, where no increase or decrease was observed in transpiration, a like relation is observed in the root growth. There was a slight increase, however, in the transpiration per unit of green growth, due perhaps to the fact that the green weight of these plants was below normal.

The general import of the experiments presented in tables V and VI seems to be that the addition of pyrogallol or tannic acid causes a marked acceleration in transpiration, and that this acceleration is correlated more with the growth of roots than of the green parts of the plant. As a consequence of this response, the amount of water transpired per unit of green weight appears larger than the response to any other agent used.

In many respects the growth of wheat plants in a soil extract previously treated with finely divided solids resembles that in extracts to which pyrogallol has been added. Undoubtedly the action of the two is similar in alleviating some unfavorable condition which previously existed, but was removed by the treatment in question. The pyrogallol must enter into chemical combination with some deleterious compounds in the soil extract or cause some process of oxidation, while the finely divided solids such as carbon black or ferric hydrate absorb and remove from solution the same deleterious substances. It is not proposed to dwell upon the general aspect of this problem in this place, since it has been treated in other papers and by various authors. The point to be demonstrated here is the effect of this treatment upon the transpiration per unit of green weight.

A large increase in transpiration is usually caused by the treatment with absorbing agents. In most cases, the substance employed as an absorbing agent was added to the soil extract, stirred or shaken frequently during a half-hour, and then filtered out before the extract was used as a culture medium for plants; but the same or slightly greater increases were produced by leaving the absorbing agent in the solution during the time the plants were growing.

Ordinary distilled water, which contains small amounts of poison-

ous metals from the distilling apparatus, together with small amounts of volatile organic substances which pass over in an ordinary still, may show similar amelioration by treatment with absorbing agents. A representative instance is shown in table VII; other cases have been given by LIVINGSTON (**9**).

TABLE VII

EFFECT OF VARIOUS ABSORBING AGENTS UPON CORRELATIVE TRANSPIRATION OF WHEAT PLANTS GROWN IN DISTILLED WATER

No.	Treatment	Transpiration	Green weight	Units water transpired per unit green weight (relative)
1	Distilled water, control	100	100	100
2	Distilled water, carbon treated	208	120	173
3	Distilled water, ferric hydrate treated	225	115	196
4	Distilled water, quartz flour treated	245	135	181

These figures show among other things that the proportional transpiration was greatly increased by these treatments. It might be argued logically that the transpiration of the plants in the untreated distilled water is abnormally low, due to the probable presence of poisonous metals in the untreated distilled water, as such substances have the effect of depressing transpiration, while the transpiration of the plants in the treated solutions is normal. The removal of these substances by the absorbing solids leaves the solution in a better physiological condition for plant growth, as evidenced by the increased transpiration and green weight. The same result is also produced to a greater or less extent by redistillation in glass.

Such treatments are generally accompanied by an increased root development, especially in branching, but as a rule this relation is not brought out in the dry weight of the roots, it being often found that a set of long, well-branched roots weigh no more than a set of shorter, more poorly branched roots of the same number of plants, due to the greater thickness of the latter. The weight of the fresh roots would be, however, a more accurate indication of the effect of the treatment, as was shown in table VI. The longer and better branched roots in the culture solutions treated with absorbing solids are to be regarded as

indicative of superior conditions for growth, and undoubtedly contribute largely to the increased transpiration.

The general effect of treatment by an absorbing agent in case of soil extracts also is to increase transpiration and root growth of the plants, although there are occasional cases where the increased transpiration is small or negative. Table VIII presents the results of a number of experiments upon this question in which a variety of soil extracts were used. The results of the experiments, made at different times, are presented in terms of the growth of plants grown in control cultures. These control results (not presented in the table) were always taken as 100, and the response to treatment with the absorbing agent expressed by proportional figures.

TABLE VIII

EFFECT ON TRANSPIRATION OF TREATING VARIOUS SOIL EXTRACTS WITH ABSORBING AGENTS BEFORE USING THEM AS CULTURE MEDIA*

No.	Soil extract	Transpiration	Green weight	Units water transpired per unit green weight
1	Elkton silt loam	178	107	167
2	Lyons silt loam	95	121	81
3	Alloway clay	465	147	316
4	Kingston soil	81	83	97
5	Takoma lawn soil	190	104	182
6	Arlington soil	142	110	128
7	Dunkirk sandy loam	96	87	110
8	Memphis silt loam	154	118	129
9	Arlington clay loam	108	110	97
10	Takoma lawn soil	137	109	125
11	Kingston soil	116	109	106
12	Memphis silt loam	117	99	119
13	Dunkirk sandy loam	114	114	100
14	Arlington clay loam	158	102	155
15	DeKalb silt loam	133	103	126
16	Cecil sandy loam	112	97	108
17	Hagerstown loam	229	102	225
18	Dutchess silt loam	110	89	122
19	Cecil sandy loam	193	114	171
20	Lyons silt loam	226	131	181
21	Penn clay	402	111	364
22	Miami black clay loam	142	98	144
23	Miami silt loam	172	123	139
24	Lyons silt loam	626	135	461
25	Park soil	136	97	153
	Average	185.3	108.8	164.2

* The absorbing agent used for treating the first 19 soil extracts was carbon black; for the remainder ferric hydroxid was used.

These results show, almost without exception, that the transpiration and growth were accelerated by previously treating the soil extract with an absorbing agent; also, that the units of water transpired per unit of green growth were greater as a result of the treatment employed. In respect to their effect upon the resulting morphogenesis of the plant, the absorbing agents resemble such substances as pyrogallol.

Discussion and summary

The studies presented in the foregoing pages are devoted mainly to an investigation of the relation of transpiration to the green growth of the plant under the influence of various chemical agents. Higher concentrations of the chemical agents were avoided, since it is well known that a sufficiently concentrated solution of a non-toxic salt will retard growth and produce the effect of a "physiological drought."

The small amounts of the respective chemical agents used had a definite influence upon the correlative transpiration. In the case of lime and sodium phosphate, the transpiration showed material increases, but potassium salts decreased it; while sodium nitrate was somewhat variable, usually operating however to cause a decrease in transpiration. Inorganic acids retarded transpiration, while organic acids were somewhat variable. Pyrogallol and tannic acid resembled the action of absorbing agents in causing large increases in the transpiration per unit of green growth.

These effects appear in all cases to be a specific action of the ions constituting any given agent. For example, K always showed its inhibiting action on transpiration, regardless of whether it was combined with Cl, NO_3, or SO_4; so also was the accelerating action of Ca. In this respect the rôle of these ions is doubtless comparable in specificity with their rôle in nutrition and other physiological processes.

The action of certain of these fertilizer constituents might be, as LAWES suggested, of practical advantage in agricultural operations. Under more or less critical conditions, it is conceivable that the effect of a salt like K_2SO_4, which retards transpiration, might make an appreciable difference in plant growth. An experimental study of this question would be extremely interesting.

There are rather extensive areas where the salts of potassium, but more especially those of sodium, are present in the soil in amounts appreciable to plant life, but insufficient to cause distinct xerophily. Since these areas usually receive scanty rainfall, it is altogether probable that the action of those ions and salts which are here shown to retard the correlative transpiration would play an important part in plant growth.

Concerning the action of pyrogallol and tannic acid, both of which greatly accelerated transpiration, but little remains to be said in this discussion. It may be added, however, that these, or closely related substances, are quite common in plants, and it is conceivable that their presence may influence transpiration independently of other factors. A similar view might be held of the action of oxalic and other organic acids which occur naturally as such in plants.

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INHERITANCE OF SEX IN LYCHNIS[1]

GEORGE HARRISON SHULL

(WITH TWO FIGURES)

Since CORRENS (**4**) made his brilliant investigations with Bryonia, in which he showed that crosses between the monoecious *B. alba* and the two sexes of the dioecious *B. dioica* do not give equivalent results in regard to the sex of the offspring, and since DONCASTER and RAYNOR (**6**) published their equally interesting studies with the currant moth, *Abraxas grossulariata*, and its variety *lacticolor*, in which it was found that reciprocal crosses were not equal with respect to sex, but that the Mendelian color character of the variety *lacticolor* is sex-limited, the interest of all students of genetics has been more or less strongly directed toward the problems of sex inheritance, and toward the attempt to describe or explain the heredity of sex on the basis of Mendelian inheritance.

It has been of great interest to find that these two classic cases of Bryonia and Abraxas apparently lead to opposite conclusions as to which sex determines the sex of the offspring, but both seem to favor the conception that one sex is homozygous with respect to sex, and the other heterozygous. BATESON (**1**) attempts to make the results with Bryonia agree with those in Abraxas, but his interpretation is certainly not as simple as that of CORRENS. BATESON'S explanation would require that *Bryonia alba* be gynodioecious, having larger numbers of pure females than of monoecists, instead of being wholly monoecious as described in the manuals. It does not seem likely that so striking a relation as this would have been overlooked by the taxonomists. Moreover, in the attempt to bring harmony between Bryonia and Abraxas, BATESON introduces fully as fundamental inharmony between the two species of Bryonia, when he assumes that the males of *B. dioica* are pure males with pollen bearing only the male character, while the pollen of *B. alba* is all female. Certainly we are justified in expecting a more complete

[1] Read by invitation before the American Society of Naturalists, Boston, December 28, 1909.

harmony among the species of a single genus than between a species of plants and a species of animals. CASTLE (**3**) has also attempted to relate the Bryonia and Abraxas types of behavior by the assumption that in each case the female is the equivalent of the male plus an *x* element, the female in Bryonia being a *positive* homozygote and the male a heterozygote, while in Abraxas the female is a heterozygote and the male a *negative* homozygote. This explanation recognizes that Bryonia and Abraxas present fundamentally different conditions.

It is not my intention to present a general discussion of the present state of our knowledge regarding the inheritance of sex, as this has been well done recently by WILSON (**12**), CASTLE (**3**), BATESON (**1**), DONCASTER (**5**), and MORGAN (**8**). However, it may be said that the number of studies which have been made in this field are entirely too few as yet to warrant far-reaching generalizations on the question of sex inheritance, and further data bearing on the subject will be awaited with great interest. It has appeared to me that a serious criticism can be offered to the results of crosses between *Bryonia alba* and *B. dioica* as a basis for conclusions regarding the whole problem of sex inheritance. These crosses are interspecific, and, as is very often true of crosses between distinct species, the sterility of the F_1 offspring did not allow any test of the correctness of assumptions regarding the gametic composition of the hybrids. While it is true that in many species-crosses in which the hybrids are fertile, certain characteristics segregate normally, it has not been uncommon to find that many characters do not segregate, or at least that their segregation is very doubtful and obscure. The simple, typical segregation of characters is best exemplified by the most closely related forms, between which also the fertility is most perfect, and this may be expected to hold true of sex characters as well as of other alternative characters.

BATESON (**1**, p. 166) has repeated the experiments with Bryonia and has fully confirmed the results of CORRENS. BATESON is also convinced of the unsafe character of the Bryonia results as a basis for generalizations, and says that "the relation of dioecious to hermaphrodite and monoecious forms will not in all probability be satisfactorily or rapidly elucidated until some case can be found in which the two types can be crossed together with a fertile result."

I have some material now in hand which meets this requirement, but have not yet continued the experiments long enough to allow more than a preliminary report upon its behavior. For several years I have been investigating the sex ratios in *Lychnis dioica* L., and for this purpose have made carefully controlled pollinations yearly in this usually dioecious species. It was my good fortune during the summer of 1908 to find among these pure-bred cultures six hermaphrodite individuals, the first which I had seen in the several years during which I had been working with this species, in which time I had examined some 8000 pedigreed individuals. In the past season I have noted eight hermaphrodites, usually more or less imperfect, in pure-bred normal families including a total of 10,320 individuals. Only two of these eight were well developed and appeared to be fully functional both as males and females.

Although the occasional occurrence of hermaphrodite individuals in this species has been frequently noted,[2] I have never seen any of them growing wild in the vicinity of Cold Spring Harbor, where the original material for my cultures was collected. STRASBURGER (11) found that hermaphrodite plants in his cultures at Bonn were invariably affected by a smut, *Ustilago violacea*, which fruits in the anthers, and he ventured the suggestion that all the reported hermaphrodites in this species may have been such diseased individuals; but, fortunately for my experiments, *Ustilago violacea* has never appeared among my Lychnis cultures, and some, at least, of the hermaphrodite individuals were capable of functioning both as males and females. Five of the hermaphrodites found in 1908 were members of a single family (0739). Several of these hermaphrodite mutants did not have the ovaries and pistils fully developed, and consequently my ability to secure offspring from them was somewhat limited. However, during the past summer, I had 13 families in which one of these hermaphrodite plants entered as either the male or female parent. Two of the six original hermaphrodites died before I had opportunity to use them in crossing. Of the remaining four, two were successfully self fertilized, and one of these was also successfully used as a mother in crosses with a normal male.

[2] See PENZIG, O., Pflanzenteratologie 1:300; and KNUTH, P., Handbuch der Blütenbiologie 2[1]:174, 175.

For convenience, I will designate the four plants successfully used in breeding by the letters *A*, *B*, *C*, and *D*. When *A* was self fertilized it produced, as a result of two different operations, 33 females and 25 hermaphrodites. When its pollen was used to fertilize four different females, the resultant progenies consisted of 236 females, 161 hermaphrodites, and 2 males. When castrated and fertilized with pollen from a normal male, *A* gave rise to a progeny of 21 females, 2 hermaphrodites, and 11 males. *B* was also self fertilized and gave a progeny of 110 females and 95 hermaphrodites. When pollen of *B* was used to fertilize three different females, it produced 162 females and 144 hermaphrodites. It is thus seen that the two plants, *A* and *B*, showed identical behavior and together produced self fertilized offspring consisting of 143 females and 120 hermaphrodites, and when crossed with females gave a total of 398 females, 305 hermaphrodites, and 2 males. In any explanation of these results the occurrence of these two males will probably have to be left aside as wholly exceptional. Only further breeding will show whether they were true males, or hermaphrodites with pistils suppressed, perhaps, by some cause external to the germ cells. Plants *C* and *D* gave quite a different result. Attempts to self fertilize them and to cross them with normal males all proved futile, though more persistent efforts perhaps might have succeeded. Both were used as pollen parents in crosses with normal females. In such a cross *C* gave a progeny of 39 females and 55 normal males, and *D* gave 26 females and 18 normal males. The details of the several crosses are given in table I, p. 114.

Considering first plants *A* and *B*, and leaving out of consideration for the present the two males occurring in crosses between females and hermaphrodites, and the two hermaphrodites which appeared in the cross between a hermaphrodite and a normal male, it is apparent that the hermaphrodite character belongs only to the males, for in the families in which these hermaphrodites were the pollen parents, the offspring always showed the same ratios of females and hermaphrodites that would have been expected of females and males, had a normal male been used as the pollen parent.

It is clear that the hermaphrodite individuals, *C* and *D*, belong to an entirely different category from *A* and *B*, for in the families

produced by using them as pollen parents, the offspring are exactly the same as if normal males had been used. In *A* and *B* the hermaphrodite character is borne by the male germ cells and is fully hereditary. In *C* and *D* the hermaphrodite character may have been purely somatic, in no wise affecting the germ cells, and therefore incapable of hereditary transmission; or, in case the factor for hermaphroditism is independent of the sex-producing genes, *A*

TABLE I

Pedigree no.	Cross	Result
08115	♀×self (*A*)	24♀:19♀
08117	♀×self (*A*)	9♀:6♀
08119	♀×self (*B*)	110♀:95♀
Total	♀×self	143♀:120♀
0869	♀×♀ (*A*)	58♀:36♀ :1♂
08118	♀×♀ (*A*)	60♀:40♀ :1♂
08127	♀×♀ (*A*)	51♀:52♀
08149	♀×♀ (*A*)	67♀:33♀
08106	♀×♀ (*B*)	53♀:50♀
08128	♀×♀ (*B*)	50♀:51♀
08150	♀×♀ (*B*)	59♀ 43♀
08125	♀×♀ (*C*)	39♀:0 :55♂
08132	♀×♀ (*D*)	26♀:0 :18♂
Total	♀×♀ { *A* and *B*	398♀:305♀: 2♂
	{ *C* and *D*	65♀:0 :73♂
08116	♀ (*A*)×♂	21♀:2♀ :11♂

and *B* may have been homozygous and *C* and *D* heterozygous with respect to the hermaphrodite modifier.

That males, which are assumed to be heterozygous and to contain both the male and female tendencies, should occasionally show the development of characters of both the sexes as the result of some accident or environmental influence upon an individual, without in any way changing the character of the germ cells produced by that individual, is quite conceivable. The occurrence of these two different types of hermaphrodite individuals harmonizes well with many experiences met with in other studies in heredity, which have led JOHANNSEN (**7**) to distinguish between genotypes and phenotypes. These four hermaphrodite individuals, *A*, *B*, *C*, and *D*, belong to a single phenotype, but to two genotypes.

If now we compare these results in Lychnis with those of CORRENS in Bryonia, still leaving out of account the two exceptional males and the two hermaphrodites which occurred in pedigree no. 08116, we find that the difference is a consistent one. This comparison may be conveniently made in the following table:

TABLE II

Cross	Bryonia	Lychnis
♀×♂	♀ and ♂	♀ and ♂
☿×♂	♀ and ♂	♀ and ♂
♀×☿	♀	♀ and ☿
☿×☿	☿	♀ and ☿

In the first place, it is seen that all crosses between normal females and normal males in Lychnis result in females and normal males, just as in *Bryonia dioica*, and the same thing is true in both cases when the hermaphrodite is fertilized by a normal male. The result of self fertilizing the hermaphrodites of Lychnis, however, is (presumably) quite different from the result of self fertilizing *Bryonia alba*, for Lychnis gives rise to a progeny of females and hermaphrodites, while Bryonia (presumably) gives rise to only monoecists or hermaphrodite individuals. A similar difference is observable between these two classes of material when normal females are fertilized by pollen of hermaphrodites, as Bryonia produces in this case only females, while Lychnis produces females and hermaphrodites.

These results suggest that the differences between Bryonia and Lychnis are rather simple ones. The fact that the hermaphrodites take the place of males in each family whose male parent was a hermaphrodite, permits no other reasonable conclusion than that the hermaphrodite Lychnis is a modified male; and the capacity of the male to be thus modified so as to allow the development of both male and female organs, strongly favors the view that the male is heterozygous, as has been assumed by CORRENS (**4**) and CASTLE (**3**) for Bryonia, and as demonstrated by WILSON and his students for many insects.

There are now several possibilities regarding the nature of the females. CASTLE (**2**) long ago suggested that the female, as well as the male, is heterozygous, but in his latest communication on sex (CASTLE **3**) he definitely abandons this view and holds that in all

cases only one sex is heterozygous and the other is homozygous; and this is the conception now generally entertained by those who adopt a Mendelian explanation of sex. According to this view, if the male is heterozygous, as has just been decided to be the case in Lychnis, the female must be homozygous. As there are two kinds of homozygotes, namely, "positive" and "negative" (SHULL **9**), there remain two possibilities regarding the nature of the female; it may be either a positive homozygote or a negative homozygote. While either of these assumptions will explain about equally well the facts brought to light in Bryonia, neither will fit all those observed in Lychnis without encountering important difficulties.

Making first the supposition that the female is a positive homozygote, as suggested by CASTLE (**3**), all conditions found in Bryonia will be satisfied if it be also assumed that *B. alba* is a homozygous monoecist (a modified female condition in this case) in which the absence of the monoecious character is dominant over its presence. The sterility of the F_1 hybrids in Bryonia unfortunately makes it impossible to test the correctness of these assumptions. It is less easy to make a positive homozygous condition of the female fit the results found in Lychnis as described in this paper. This can be done, however, by assuming: (*a*) that all egg cells of both females and hermaphrodites carry the gene for the female sex, and not that for hermaphroditism; and (*b*) that all the sperms of the hermaphrodites carry a gene for the hermaphrodite modification, regardless whether they possess the gene for the female sex (the "*x* element") or not. The first of these assumptions seems necessary from the fact that the results are identical in each case, whether a female or a hermaphrodite is used as the female parent; and the second from the fact that females and hermaphrodites result from pollinating a normal female by pollen from a hermaphrodite. The second proposition might be replaced by one involving spurious allelomorphism. It is expected that a second generation will demonstrate the correctness or incorrectness of these several hypotheses.

The alternative assumption, namely, that the female is a negative homozygote, will just as simply represent the conditions of the F_1 generation. If the monoecious character in Bryonia be considered a modified male condition similar to the hermaphrodite character of

Lychnis, the difference between Bryonia and Lychnis is reduced to a question of dominance of the hermaphrodite (or modified male) condition. In order that *Bryonia alba* should breed true, the monoecious (or modified male) character must be homozygous. The fact that in Bryonia a cross between the female *B. dioica* and the monoecious *B. alba* produces only females, indicates that the monoecious character is capable of coming to full expression only when present in the homozygous state. In other words, while the monoecists are modified positive male homozygotes, absence of this modified male character is almost perfectly dominant over its presence, so that the heterozygous individuals which constitute the F_1 of this cross almost or quite completely lack the male character. In this connection the occurrence of occasional male flowers on a few of these females of the F_1 may be of interest as showing a slight influence of the unpaired gene for the modified male or monoecious sex.

In Lychnis, on the other hand, the presence of the hermaphrodite character is dominant over its absence, as demonstrated by the fact that the hermaphrodite mutants are heterozygous with respect to sex. In the following table a comparison may be made between the two methods of explaining the character of the F_1 hybrid generation:

TABLE III

Cross	Bryonia			Lychnis		
	Assumed character of parental gametes	Resultant composition of offspring	Somatic type of offspring	Assumed character of parental gametes	Resultant composition of offspring	Somatic type of offspring
Assumption: The female is a positive homozygote						
♀×♂	♀♀×♀	♀♀ and ♀	♀ and ♂	♀♀×♀	♀♀ and ♀	♀ and ♂
☿×♂	☿☿×♀	☿☿ and ☿	♀ and ♂	♀♀×♀	♀♀ and ♀	♀ and ♂
♀×☿	♀♀×☿☿	♀☿	♀	♀♀×☿	♀☿ and ☿	♀ and ☿
☿×☿	☿☿×☿☿	☿☿	☿	♀♀×☿	♀☿ and ☿	♀ and ☿
Assumption: The female is a negative homozygote						
♀×♂	♀♀ ×♀♀♂	♀♀ and ♀♀♂	♀ and ♂	♀♀×♀♀♂	♀♀ and ♀♀♂	♀ and ♂
☿×♂	♀♀☿☿×♀♀♂	♀♀☿ and ♀♀☿♂	♀ and ♂	♀♀×♀♀♂	♀♀ and ♀♀♂	♀ and ♂
♀×☿	♀♀ ×♀♀☿☿	♀♀☿	♀	♀♀×♀♀☿	♀♀ and ♀♀☿	♀ and ☿
☿×☿	♀♀☿☿×♀♀☿☿	♀♀☿☿	☿	♀♀×♀♀☿	♀♀ and ♀♀☿	♀ and ☿

No decision can be made between the two methods of explanation contrasted in this table until the F_2 has shown the dependence or

independence of the gene whose presence results in the hermaphrodite modification of the male. If the females may carry the hermaphrodite modification as a latent character, and if the hermaphrodites of the F_1 differ in their gametic composition from those of the P_1 generation, the hypothesis that the female is a positive homozygote may be substantiated; but if the hermaphrodites of the F_1 are identical in their behavior with those of the P_1, and if the hermaphrodite modification cannot be transmitted through the female, the results will support the hypothesis that the female is a negative homozygote.

It is not at all improbable that the hermaphrodites discussed above as *C* and *D* differed from *A* and *B* in having the gene for the hermaphrodite modification in the heterozygous state, while *A* and *B* were homozygous with respect to this gene. If this should be correct, then *C* and *D* were of the type which will appear in the F_1 of crosses between normal females and such hermaphrodites as *A* and *B*, in case the hermaphrodite modification is independent of the male germ cells. The occurrence of such hermaphrodites as *C* and *D* may be accepted as rather favorable to the view that the female is a positive homozygote.

There is one fundamental difficulty with any hypothesis which assumes that the hermaphrodites are heterozygous. The eggs of these hermaphrodites are of a single kind with respect to sex, all carrying the female character. This difficulty is inherent in the material itself, however, and is not opposed in any way to the assumption that the normal females are either positive or negative homozygotes, for the male germ cells of the hermaphrodites are clearly of two types as required by the hypothesis that these hermaphrodite plants are heterozygous. Cytological investigations of oogenesis in the hermaphrodites may perhaps give a complete solution to the exceptional situation presented by the egg cells. If the females are positive homozygotes there may be simply a failure of those eggs to develop which do not possess the gene for the female sex. If the female is a negative homozygote, there may be a failure of those eggs which possess the male gene, or there may be an exclusion of this gene during oogenesis.

While I have left out of account the two hermaphrodite individuals in the cross (08116) between a hermaphrodite and a normal male,

I am not unmindful of their possible importance. The number of offspring of this combination was too small to enable one to be sure that these are not mutants which bear no necessary relation to the fact that their mother was a hermaphrodite. It was found particularly difficult to secure offspring of crosses of this type, as the flowers were very often caused to drop off as a result of the process of castration. Very often also in the flowers of hermaphrodite plants the pistils are immature at the time the anthers are ready to open, and after castration these pistils frequently develop no farther, in which case there is no possibility of effecting fertilization. The occurrence of these two hermaphrodite plants in no. 08116 offers a further suggestion that the hermaphrodite character may be capable of independent movement, and that consequently it may be carried in some manner or to some degree by the female. This suggestion especially commends itself from the fact that the occurrence of the male and female organs on the same plant, as CORRENS (4) has pointed out, constitutes in effect a mosaic, and it is well known that mosaic inheritance is often dependent upon the presence of a definite separate unit for the mosaic condition. If further investigation should demonstrate that the hermaphrodite character may be transmitted through the female, as is suggested by this one family, we will be forced to the conclusion that here also the existence of a unit for the mosaic condition is present. In whatever manner the male may be converted into a hermaphrodite, the results seem to demonstrate that in Lychnis, as in Bryonia, *it is the male which is heterozygous* and which carries both male- and female-producing genes as concluded by CORRENS, and not the female as assumed by BATESON.

The demonstration that the hermaphrodite of *Lychnis dioica* is a modified male indicates that STRASBURGER (11) was mistaken in his interpretation of the effects produced by *Ustilago violacea* upon this species. He believed that the infected plants were females in which the development of stamens was stimulated by the attack of the fungus. Instead of this it is probable that they were males in which the disease somewhat lessened or modified the dominance of the male character, thus allowing the female organs to develop; or, if the female is a positive homozygote, the disease may be assumed to have stimulated the single female gene or *x* element of the male

to develop the female organs as well as the male organs. STRASBURGER states that the development of the stamens in the diseased plants was correlated with an elongation of the floral axis between the calyx and corolla (a character peculiar to flowers of the male plants), and that not infrequently the infected plants gave the impression that they were males. On the other hand, the fibrovas-

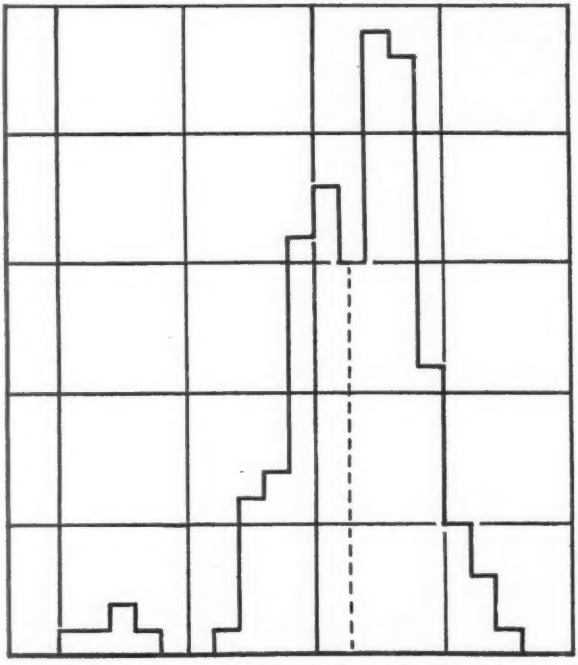

FIG. 1.—Variation in percentages of females in 135 families of *Lychnis dioica*.

cular system of the calyx in infected plants more nearly assumed the distinctive features of the normal female flowers. The appearance of this secondary female character may be as readily accounted for as the appearance of the female sex organs themselves, on the ground of modified dominance of the male or of the female character in a heterozygous male.

CORRENS has pointed out that the determination of sex ratios is quite a different matter from the determination of sex, and we must

maintain that this is so, provided sex is inherited as a Mendelian character. But if sex inheritance be not primarily Mendelian, but only associated with and perhaps determined by Mendelian charac-

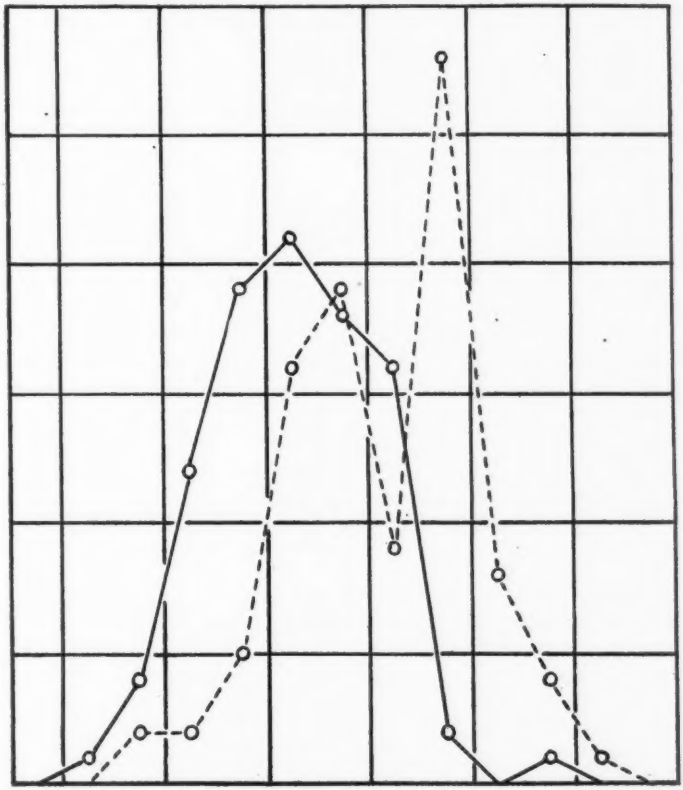

FIG. 2.—Variation in percentages of females and in percentages of purple-flowered plants in 94 families of *Lychnis dioica* produced by crossing heterozygous purple with white; broken curve represents females; both curves if monomodal belong to PEARSON'S Type I. See constants in table IV.

ters in a few cases, the determination of a sex ratio might not be a process distinct from the inheritance of sex itself.

The assumption that the sexes differ from each other by a single unit character, and that one sex is heterozygous and the other homo-

zygous with respect to this character, would demand equality in the average numbers of the two sexes; but each year *Lychnis dioica* has produced on the average a considerable excess of females, while the ratios in different families range all the way from less than 5 per cent. female to nearly 90 per cent. female. The percentages of females in 135 families reared during the summer of 1909 are shown in the form of a variation curve in *fig. 1*. It is difficult to believe that a family of 4 females and 100 males or of 87 females and 10 males is theoretically referable to a ratio of 1:1. In 1909 my cultures of *Lychnis dioica*, taken collectively, consisted of 6366 females and 4831 males (including hermaphrodites), or a ratio of 1.32:1, which agrees very well with ratios between 1.20:1 and 1.40:1 reported by STRASBURGER (**11**). After carrying on extensive experiments on the influence of various environmental factors, with negative results, STRASBURGER reached the conclusion that the sex ratio is determined by inherent factors. This is only another way of saying that it is hereditary in some sense. I have been attempting for several years to test the heredity of the sex ratios, but have not yet found the key to the situation. It is hoped that the numerous crosses which have been made will in the near future throw some light upon the significance of these exceedingly variable ratios and allow the causes which determine them to be understood.

In order to compare the variation in these sex ratios with that in a character known to be Mendelian, I have plotted curves representing the percentage of females and the percentage of purple-flowered individuals in all families (94 in number) raised during the years 1907, 1908, and 1909, which were produced by the union of heterozygous purple with white (see *fig. 2*). The variation constants of the two curves appear in the following table:

TABLE IV

VARIATION CONSTANTS OF CURVES CONTRASTED IN *fig. 2*

	Percentage females	Percentage purples
Mean	61.223 ±0.630	52.606 ±0.551
Standard deviation	9.051 ±0.445	7.925 ±0.490
Coefficient of variability	14.784 ±0.742	15.064 ±0.758
Theoretical mode	62.933 ±0.686	52.353 ±0.600
Coefficient of skewness	−0.0990±0.0062	+0.0282±0.0062

Aside from the remarkable difference in the value of the means, the two curves are skewed in opposite directions, the strong negative skewness and suggested bimodality of the sex curve, as contrasted with the nearly normal character of the curve for color, being particularly noteworthy. The variability represented by these two curves is properly compared by means of the standard deviations, and not by the coefficient of variability, since we are dealing here with groups of variates having similar theoretical limits of range, and similar expected mean values. On this basis the sex ratios show considerably greater variability than those of the color character. This is especially interesting in view of the fact, pointed out elsewhere (SHULL **10**), that crosses between heterozygous purple and white *Lychnis dioica* may frequently result in other ratios than 1:1, owing to the part taken by several distinct genes in the production of the purple colors in this species, and that therefore the data for the color curve may be somewhat heterogeneous, while the sex data are at present assumed to be homogeneous.

Summary

Hermaphrodite mutants occur in pure-bred families of *Lychnis dioica* L., the ratio of mutability being somewhat less than 1:1000.

None of these hermaphrodites was diseased and several were fully functional both as females and males, thus negativing the suggestion of STRASBURGER that the hermaphrodites in this species may always be due to the attacks of the smut, *Ustilago violacea*.

In their hereditary relations these hermaphrodites were of two kinds, some behaving like normal males, others having the capacity of transmitting the hermaphrodite character to their male offspring. This second class of hermaphrodites when self fertilized, or crossed with normal females, gives progenies consisting of normal females and hermaphrodites, and when fertilized by normal males gives normal females and normal males.

The hermaphrodite individuals are modified males, for in all families in which these hermaphrodites were the pollen parents the offspring showed the same ratios of females and hermaphrodites as would have been expected of females and males had a normal male been used as the pollen parent.

These results agree in a general way with those of Bryonia in that they demonstrate the homozygous character of the females and the heterozygous character of the males in Lychnis.

Whether the females are positive or negative homozygotes cannot be determined from the F_1, as both assumptions can be made to fit the facts by the aid of simple correlative hypotheses whose correctness or incorrectness can be determined only by further breeding.

A fundamental difficulty in either case is found in the fact that the egg cells of the hermaphrodites are apparently of a single type, all possessing the female-producing gene. The assumption that the hermaphrodites are heterozygous leads us to expect equal numbers of two different types of egg cells. Cytological studies may perhaps explain this difficulty. The male germ cells of the same plants are of two types, as required by theory.

The occurrence of two hermaphrodite individuals in a progeny produced by a cross between hermaphrodite and normal male suggests the possibility that the hermaphrodite character may also be transmitted through the female. This fact, together with the occurrence of two genotypes among the hermaphrodites, is held to be slightly favorable to the view that the female is a positive homozygote.

The demonstration that the hermaphrodite individuals of Lychnis are modified males indicates that STRASBURGER was mistaken in assuming that his hermaphrodites were diseased females. They were probably diseased males in which the dominance of the male character was modified by the fungus.

The sex ratios in Lychnis do not accord well with a theory of sex which requires males and females to be present in equal numbers. The ratios found in my cultures are in accord with those found by STRASBURGER, the average for the past year being 1.32 females to 1 male, with a very wide difference in the ratios of different families. The significance of these ratios is not yet understood.

When the variability in the sex ratios is compared with that in ratios produced by crossing heterozygous purple with white-flowered individuals, it is found that not only is there an undue departure in the sex ratios from the expected ratio 1 : 1, but also that there is greater variability in the sex ratios than in the color ratios, and that the curve is strongly negatively skewed and possibly not monomodal; while the

color curve derived from the same families is nearly normal; with the mean departing but little from the 50 per cent. required by Mendelian theory.

STATION FOR EXPERIMENTAL EVOLUTION
COLD SPRING HARBOR, LONG ISLAND

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30219

THE REFORESTATION OF SAND PLAINS IN VERMONT
A STUDY IN SUCCESSION

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 135

CLIFTON DURANT HOWE

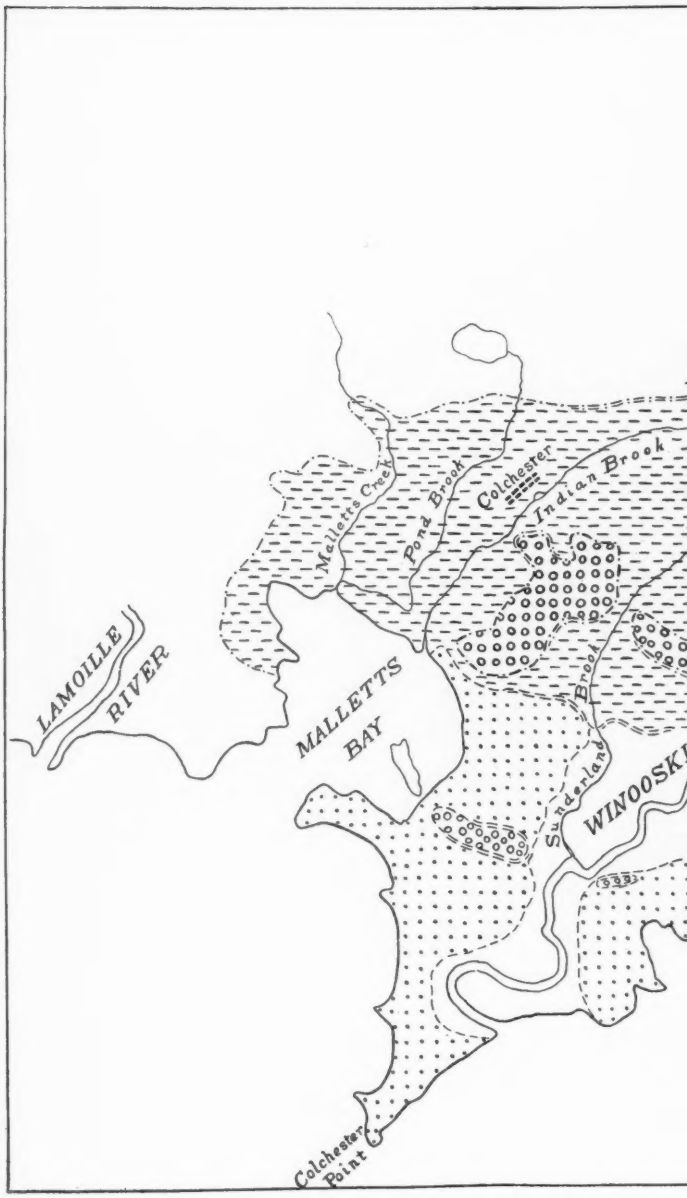
(WITH MAP AND FIFTEEN FIGURES)

Geology

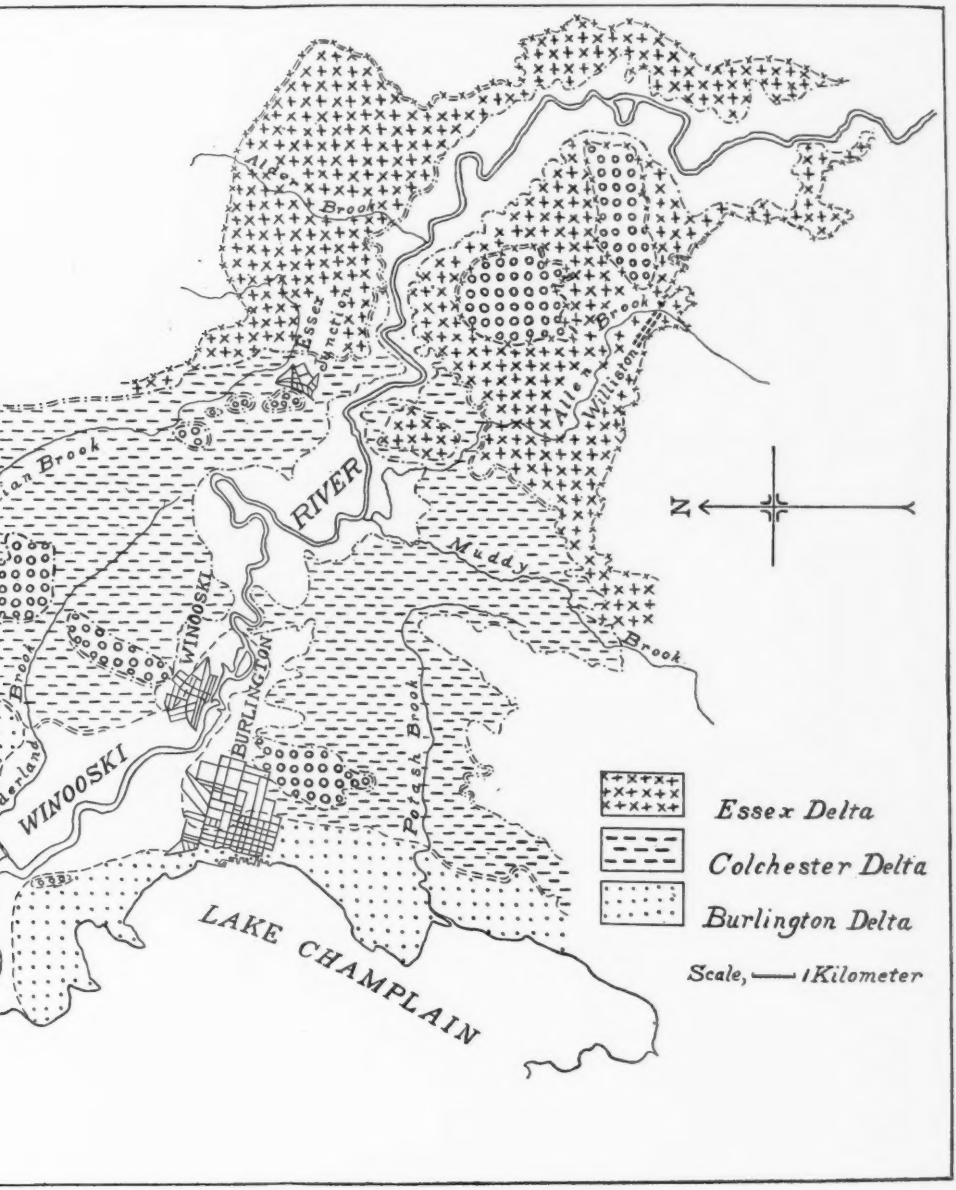
The region of this study is known as the Burlington-Colchester-Essex sand plains, which are situated at the mouth of the Winooski River, that flows into Lake Champlain from the Vermont side. The history of the plains is intimately connected with that of Lake Champlain. Previous to the Glacial period the present valley of the lake was occupied by a river[1] flowing northward. With the melting of the ice sheet a large lake was formed in the former river valley. After the Glacial period the sea invaded the region from the north, constituting what the older geologists called the Champlain epoch. At this time extensive beds of clay were laid down. The marine nature of these clays is demonstrated by the frequent occurrence of salt-water shells and by a skeleton of a whale found imbedded in them in the township of Charlotte. The Champlain epoch closed with an elevation of land which raised the marine deposits to their present location, the highest elevation being about 100^{m} above the present lake. With the withdrawal of the sea the valley was again occupied by a body of fresh water, the present Lake Champlain.

At some time during the glacial and post-glacial history of Lake Champlain outlined above, bodies of water occupied three well-marked levels. During each of these stages a delta was formed by the erosion deposits brought down by the Winooski River. From the townships in which they are located, these deltas are designated on the accompanying map, from oldest to youngest, as the Essex delta, the Colchester delta, and the Burlington delta. The broken lines on the east side of each delta represent the beach lines of the lake (or sea) during the successive elevations. The doubling of the broken lines

[1] BALDWIN, S. P., Am. Geol. 13:170–184.



Map of the Burlin



OF THE BURLINGTON-COLCHESTER-ESSEX SAND PLAINS

denotes the presence of fossil beaches, usually accompanied by low sand dunes. The areas designated by circles were islands. Those in the Essex delta are schistose rock covered with unassorted glacial till and were not submerged. Those in the Colchester and Burlington deltas, however, were submerged during the Essex stage, being limestone outcrops with the exception of the group of small islands just northwest of Essex Junction, which are schistose rock. The island south of Essex Junction, across the river, is an isolated portion of the Essex delta.

The unshaded areas on each side of the Winooski River indicate its erosion channel through the deltas. The deltas have also been much dissected by smaller streams, but their erosion channels have not been shown on the map.

The elevation of the Essex delta plain is 149^{m}, of the Colchester delta plain 98^{m}, and of the Burlington delta plain 68^{m} above the sea. Since the mean level of Lake Champlain is 30^{m}, these deltas are 119, 68, and 38^{m} respectively above the present lake level.

The surface layer of soil on each of the three delta plains is sandy, varying from pure sand to sandy loam. The texture of the sand is fine and remarkably uniform throughout, and its depth ranges from a few centimeters to 7^{m}. The subsoil of the whole area is clay. The Winooski River and its tributaries have exposed large areas of this clay, which, mixed with the sand, makes excellent farm lands. The discussion which follows, however, is confined to the vegetation of the sand plains of the three deltas, which occupy an area 36^{km} long and on the average 14^{km} wide.

Original forest conditions

While the early historians mention the dominance of pine on the area under consideration, they indicate the dominant species only by inference. For example, THOMPSON[2] says: "Along the western part of the state and bordering on Lake Champlain are extensive tracts of light sandy soil which were originally covered with white, pitch, and Norway pine." The testimony of the oldest inhabitants who took part in the clearing of the areas is that white pine was the dominant

[2] THOMPSON, ZADOCK, History of Vermont, natural, civil, and statistical. Burlington. 1842.

tree. The prevalence of old white pine stumps beneath the present forests, as well as the numerous white pine stump fences throughout the sand plains townships, contribute corroborative evidence. The original forest evidently contained some large trees, judged from present standards. THOMPSON (*l. c.*) states that he had observed trees 52^m high, and adds that originally trees 43 to 55^m high, having a diameter of 2^m, were not uncommon. Stumps in various stages of decay which were originally at least 1.5^m in diameter may be seen frequently on the sand plains.

In the clearings for settlement the commercial use of white pine was strictly local and very limited. Later came the period of utilization on a larger scale. As early as 1800[3] great rafts of pine logs taken from the sand plains were floated down to Quebec and thence exported. In 1842 the historian THOMPSON (*l. c.*) asserted that the forests of white pine in the Champlain region had practically disappeared. In 1850 (DAVIS, *l. c.*) the importation of white pine from Canada began.

The pitch pine (*Pinus rigida*) doubtless occupied small scattered areas on the most sterile soils. Black oak and white oak (*Quercus velutina* and *Q. alba*) are now common on the sand plains, and they probably formed a minor part of both the original white pine and pitch pine forests. Norway pine (*Pinus resinosa*) is now very local in its distribution on the sand plains, and it probably always was so. No record is to be found in regard to white birch (*Betula populifolia*); for reasons to be discussed later it is doubtless much more abundant now than originally.

Succession

The succession on the Burlington, Colchester, and Essex sand plains is of two classes in respect to its place of origin, namely, upon cut-over areas and upon abandoned cultivated fields.

SUCCESSION ON CUT-OVER AREAS

As stated above, historical evidence clearly indicates that white pine was orginally the controlling tree on the Burlington, Colchester, and Essex delta plains. Only isolated trees of the original stand now

[3] DAVIS, W. T., The New England states **3**:1524–1526.

remain. The conditions following the first cutting favored the invasion of the pitch pine upon areas which it had not previously occupied. In the first place, having no value at that time, it was not cut, so that seed trees were plentiful, a thing that cannot be said of the white pine; in the second place, pitch pine produces seed more abundantly than the white pine; and finally, being more light-demanding and being able to endure more sterile soil conditions, it is better adapted for regeneration on areas cleared by lumbering. Whatever the causes may have been, pitch pine became the controlling tree of the second generation, especially on the Colchester plain. A representative list chart in a stand 60 years old shows 2.5 pitch pine on $25^{sq\,m}$. Beneath on one square meter are 18 *Myrica asplenijolia*, 5 *Pteris aquilina*, 7 *Kalmia angustijolia*, 30 *Vaccinium pennsylvanicum*, 11 *Vaccinium vacillans*, 4 *Carex pennsylvanica*, 4 *Diervilla Lonicera*, 3 *Solidago* sp. (rosettes), 2 *Rubus allegheniensis*.

The soil on the Burlington and Essex plains being as a whole less sandy, there is a larger proportion of mixed stands. On the average, black oak and white oak form one-third of the pitch pine stands. White pine of the second generation is more common on these two plains.

Three brickyards and a limekiln within the sand plains furnish a market for pitch pine as fuel, and the pitch pine forests have been cut for this purpose, so that by far the greater part of the area is now in its second cycle of reforestation. The stands are usually cut clean of both trees and saplings, the latter being taken down to 5^{cm} in diameter. Sometimes a few isolated pines are left for seed trees, but they almost invariably die of the exposure resulting from clean cutting. The removal of the trees stimulated the development of the undergrowth, so that in most cases Myrica and Pteris became the dominant plants, and beneath them is a carpet of blueberries (*V. pennsylvanicum* and *V. vacillans*). If fire runs through, as it usually does periodically, the association becomes so dense as to allow no reproduction of trees. Often as many as 60 Myrica plants may be found on a square meter. The fire also keeps down the coppice shoots from the oak stumps. Some areas cleared 25 years ago are still practically without tree reproduction.

When the Myrica-Pteris association is 15 to 20 years old, and when

it has not been rejuvenated in the meantime by fire, it begins to die out, apparently from natural causes. The open places thus made give an opportunity for the reestablishment of pitch pine. The few lots on which this was noted show pitch pine seedlings at the rate of

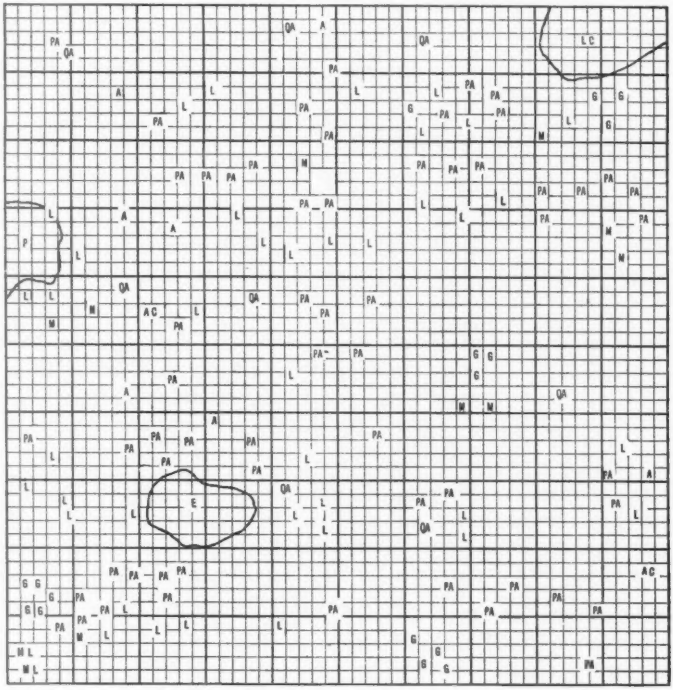


FIG. 1.—Sample plot 15. Cleared 15 years ago, Colchester plain, 5 meters square; under layer controlled by *Vaccinium pennsylvanicum* and *Kalmia angustifolia;* QA. *Q. alba* 8; A, *Acer rubrum* 5; AC, *Amelanchier canadensis* 2; PA, *Pteris aquilina* 56; L, *Lysimachia quadrifolia* 38; G, *Gaultheria procumbens* 14; M, *Myrica asplenifolia* 9; LC, *Lycopodium complanatum;* P, *Polytrichum;* E, *Epigaea repens;* ML, *Melampyrum lineare* 2.

one to 50$^{sq\ m}$; older stages were not found. It seems probable, however, that eventually, if unmolested by man, such areas will regain their dominance of pitch pine.

In cases where fire is kept out from the time of clearing, however,

reforestation takes place more rapidly. This is brought about first by the coppice shoots of the oak and by the filling-in of the intervening spaces by white birch (*Betula populifolia*), trembling aspen, red maple, and Amelanchier. Thus, on a lot cut two years ago, black

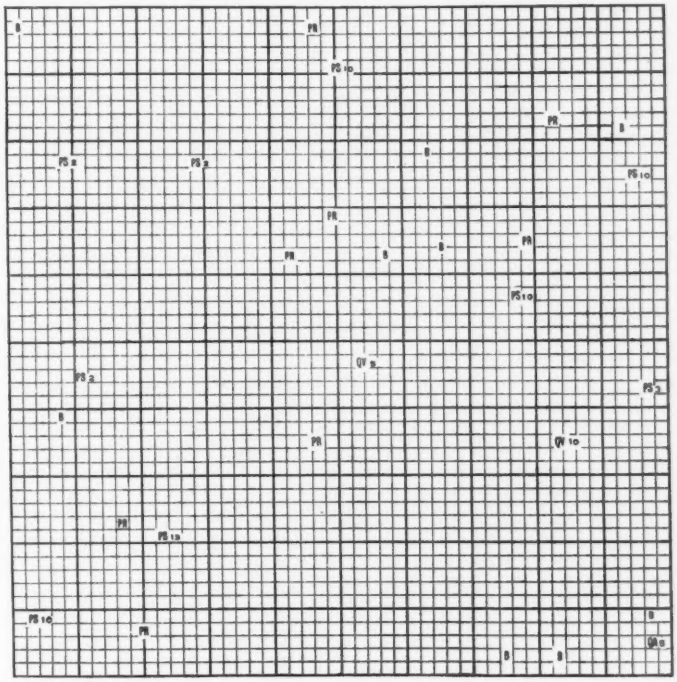


FIG. 2.—Sample plot 2. Pitch pine stand, 30 years old, Colchester plain, 5 meters square; under layer controlled by Pteris, Gaultheria, and *Vaccinium vacillans;* PR, *Pinus rigida* 8; QV, *Q. velutina* 2; QA, *Q. alba* 1; B, *Betula populifolia* 7 (dying); PS, *Pinus Strobus.*

oak coppice groups averaged three on $25^{sq\,m}$, while on the lot as a whole, 10 per cent. of the coppice was white oak and 6 per cent. red maple. A dominant stand of pitch pine 24 years old was removed from the lot and a list chart showed on one square meter 9 Myrica, 12 Pteris, 4 *Populus tremuloides*, 22 *Kalmia angustifolia*, 34 *Vaccinium pennsylvanicum*, 1 *Rubus allegheniensis.*

A stand of pitch pine 45 years old with suppressed black oaks averaging one and three respectively per $25^{sq\,m}$, was cut clean eight years ago. An average square meter now supports 3 coppice groups of black oak, 3 *Corylus americana*, 1 *Amelanchier canadensis*, 1 *Salix humilis;* under layer, Myrica and Pteris; beneath this, Kalmia, *Vaccinium vacillans*, *Lysimachia quadrifolia*. The sample plot (*fig. 1*) discloses the present conditions of a lot from which pitch pine was removed 15 years ago.

When the coppice stands of oak are about 15 years old, they cover the area sufficiently to shade out much of the under vegetation. Myrica is the first to show the effects of this shading and Pteris goes next, while the species of Vaccinium persist longer than either Myrica or Pteris, *V. vacillans* enduring the competition with the trees longer than *V. pennsylvanicum*. At this stage the pines begin to reestablish themselves. Pitch pine because of its greater intolerance comes into such areas very sparsely and very slowly. Only one place was found where it had gained control, and even there the stand seems destined to be displaced by the more shade-enduring white pine, as the sample plot (*fig. 2*) shows.

For the reasons stated above, white pine is establishing itself on the clean-cut areas, formerly controlled by pitch pine, to a greater extent than the pitch pine. For example, in a lot cut 12 years ago, on $25^{sq\,m}$ one finds 8 white birch saplings, 3 black oak coppice groups, 6 pitch pine seedlings, and 3 white pine seedlings; this is 100^{m} from white pine seed trees. A distance of 50^{m} from seed trees there are on $25^{sq\,m}$ 3 black oak coppice groups, 2 *Amelanchier canadensis*, 1 white birch, 1 red maple, 2 pitch pine seedlings, and 13 white pine seedlings. A still older stand is shown in sample plot no. 14 (*fig. 3*).

The best white pine reproduction on clean-cut areas, however, is found where white birch controls. Thus in a clean cutting of 12 years ago, there are now 2 white birch coppice groups, 25 birch saplings and seedlings, 6 red maple coppice groups, 20 *Viburnum acerifolium*, 17 *Corylus americana*, 3 *Rhus typhina*, 4 Myrica, 20 *Vaccinium vacillans*, 2 white pine (8 years old); *Polytrichum commune* and *Carex pennsylvanica* dominant beneath. This plot is 100^{m} from a white pine seed tree. Another plot of the same size ($25^{sq\,m}$) cleared

15 years ago and only 5^{m} from a seed tree, shows 44 white pine seedlings mostly 4 and 8 years old. The seedlings are practically all on little hummocks covered with Polytrichum and Mitchella. The plot

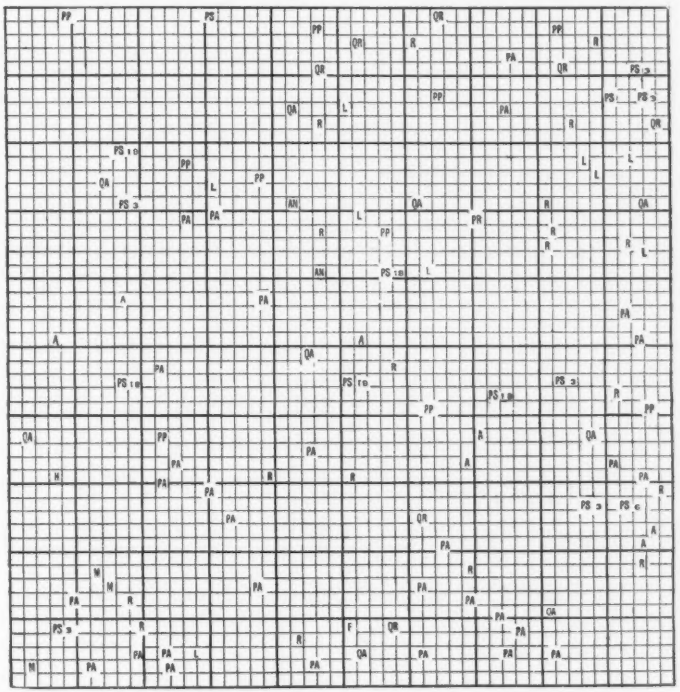


FIG. 3.—Sample plot 14. Cleared 20 years ago, Essex plain, 5 meters square; PS, *Pinus Strobus* 14; QA, *Quercus alba* 8; QR, *Q. rubra* 7; A, *Acer rubrum* 6; PP, *Prunus pennsylvanica* 10; PA, *Pteris aquilina* 29; R, *Rubus allegheniensis* 15; L, *Lysimachia quadrifolia* 9; M, *Myrica asplenifolia* 3; AN, *Aralia nudicaulis* 3; V, *Vaccinium vacillans* 2; F, *Fragaria* sp. 1; H, *Hamamelis* 1.

also contains one white pine sapling, 4 white birch and 3 black oak saplings, 3 Hammamelis, and 8 Corylus.

White birch in competition with oaks and pines persists only 20 to 30 years. Thus in a representative stand of this age one finds on $25^{sq\,m}$ 5 white pine (5 to 14 years old), 2 black oak, 1 white oak, 3 white birch (nearly dead). When such stands are 35 years old the white

birch usually has disappeared, and they average on 25 $^{sq\,m}$ 2.2 white pine, 2.4 black oak, 0.6 white oak. Although the black oak appears in slightly greater numbers, the majority of them are suppressed and white pine dominates the stand.

Thus it will be seen that the clean-cut areas which pass through the white birch stage in their reforestation end in the control of the white pine, and that those areas passing through the oak coppice and Myrica-Pteris stages are more generally succeeding to white pine than to pitch pine.

SUCCESSION UPON ABANDONED CULTIVATED FIELDS

The writer had no means of determining definitely how long the various fields had been cultivated before abandonment, but the indications are that the period was relative y short, on the average probably not more than 10 years. In some cases the fields never produced any other cultivated crop than rye, while in others they were cultivated 30 or 40 years before final abandonment. Occasionally an old field partially reforested is cleaned off and a second attempt at cultivation is made.

According to the conditions in which it takes place, the succession leading to the dominance of the forest upon abandoned fields may be discussed under the following heads:

1. Succession lacking the preliminary herbaceous stages. This occurs when a plowed field near a mature stand of trees happens to be abandoned in a heavy seed year.

2. Succession lacking the sod-forming stage. The herbaceous stages are present but the complete control of grasses is absent or short-lived.

3. Succession possessing the sod-forming stage. The natural course of succession here is interrupted by man, for these areas are cropped for grass or pastured for a longer or shorter period before the trees begin to take possession.

1. SUCCESSION LACKING THE PRELIMINARY HERBACEOUS STAGES.—This occurs when the abandonment of a plowed field and an abundant seed year are in conjunction. For example, a field on the Colchester plain first bore a crop of rye, then a crop of beans, and lay fallow the third year, when it was seeded down to white birch from the trees

which surrounded the field. White birch seedlings two years old and *Spiraea tomentosa* now occupy the field at the rate of 53 and 4 respectively per square meter. A stand of pitch pine 16 years old showing 63 trees on $25^{sq\,m}$ came into existence in the same manner. A sample plot in this stand is given below (*fig. 4*). The oaks beneath are 4

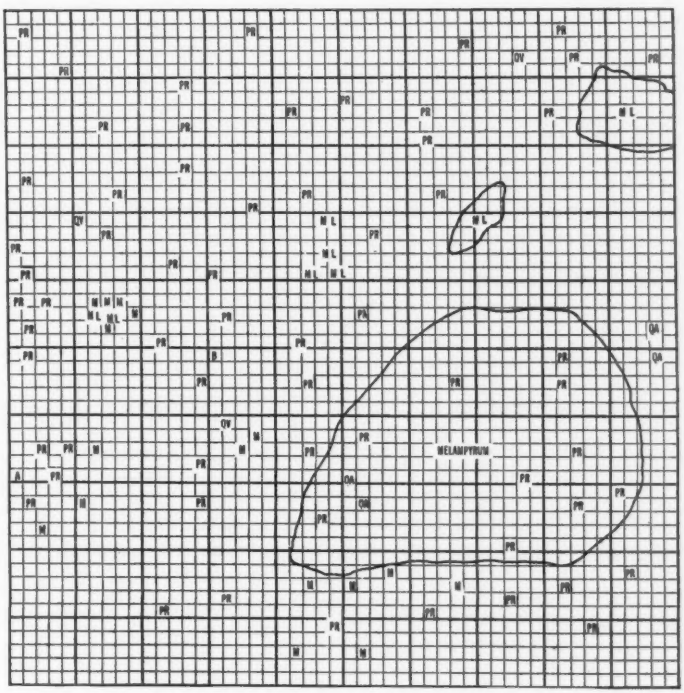


FIG. 4.—Sample plot 16. Pitch pine 16 years old, on abandoned plowed field, Colchester plain, 5 square meters; PR, *Pinus rigida* 63; QA, *Q. alba* 5; QV, *Q. velutina* 3; ML, *Melampyrum lineare;* M, *Myrica asplenifolia* 16.

years old. Other dense even-aged stands of both white birch and pitch pine probably had a similar origin, although the history of their inception is not actually known.

2. SUCCESSION LACKING THE SOD-FORMING STAGE.—The character of the vegetation on a plowed field the first year after abandonment apparently depends upon the kind of weed seeds in the fertilizer.

The quadrant below (*fig. 5*) gives the characteristic plants of a field which supported a crop of rye in the preceding year. Some fields may be controlled by *Setaria glauca* and *Setaria viridis;* others by *Ambrosia artemisiifolia* and *Erigeron canadensis.* Fields under observation

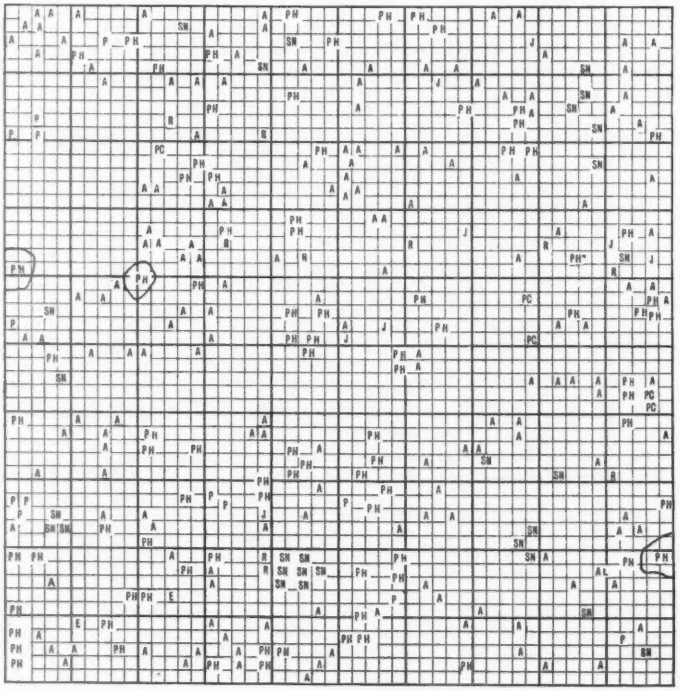


FIG. 5.—Sample plot 24. Plowed field, abandoned one year, Colchester plain, 1 square meter; A, *Ambrosia artemisiaefolia* 155; PH, *Phleum pratense* 82; SN, *Solidago nemoralis* 26; P, *Poa compressa* 14; PC, *Panicum capillare* 4; R, *Rumex Acetosella* 7; J, *Juncus* sp. 6; E, *Erigeron canadense* 2; AL, *Aster linariifolius* 1.

for 4 years have remained under the dominance of these annuals. Later, *Oenothera biennis, Rumex Acetosella, Gnaphalium polycephalum, Antennaria plantaginifolia, Solidago memoralis,* and *Aster linariifolius* control the old fields in patches. Between these patches occur scattered groups of *Cyperus filiculmis, Carex pennsylvanica, Andropogon scoparius,* and *Danthonia spicata.* Groups of Poly-

trichum appear in the most sterile places. Driving out the biennial and perennial weeds, the groups unite and form patches of moss a meter or more in diameter. The moss in turn may be crowded out by Cyperus and Danthonia, but it is never entirely displaced. Patches of Polytrichum often occupy one-third of the area in old fields.

Some of the plowed fields were abandoned because they began to blow away, and they have since become areas of shifting sand. This is notably the case in several places in the townships of Colchester and South Burlington. The finest sand is piled up in low dunes and the coarser grades left behind are packed hard by the wind. *Cyperus filiculmis* and *Panicum sanguinale* are the pioneers on the compact sand; the former occurs in groups, while the latter advances *en masse* upon the sand. The open spaces between the groups of Cyperus are filled up by Polytrichum.

The patches of Polytrichum in the abandoned fields described above form ideal germinating beds for the seeds of pitch pine, white pine, and white birch. This is particularly the case when the Polytrichum is young, before the dead leaves and stems have accumulated sufficiently to prevent the seeds from reaching the mineral soil. Usually, however, Myrica precedes the tree invasion. It starts in the bed of Polytrichum and itself forms patches, killing out the moss immediately beneath it. The Polytrichum, however, persists around the margins of the Myrica group and in the moss, and under the protection of the Myrica one finds the tree seedlings.

The rapidity with which trees take possession of the abandoned fields of this type chiefly depends upon the proximity of seed trees. Thus a field 370^{m} from seed trees, abandoned 20 years ago, has only 41 white birch and 6 pitch pine saplings per hectare. When the pines get old enough to produce seed, a group of young trees will be formed about each mother tree. Fields showing two generations of pitch pine formed in this manner are of common occurrence and those showing three generations are not rare. The white birch, being shorter lived and less tolerant than the pine, is gradually suppressed, and the result is a pure stand of pitch pine of uneven age. A list chart in the field mentioned above shows on one square meter 16 *Solidago memoralis*, 24 *Carex pennsylvanica*, 18 *Lysimachia quadri-*

folia, 8 *Aster linariifolius*, 6 *Danthonia spicata*, 2 *Ambrosia artemisiifolia*, 1 *Viola arenaria*, 1 group of *Andropogon scoparius*.

When the abandoned field happens to be near a mature stand of pitch pine, the reforestation is much more rapid. For example, an

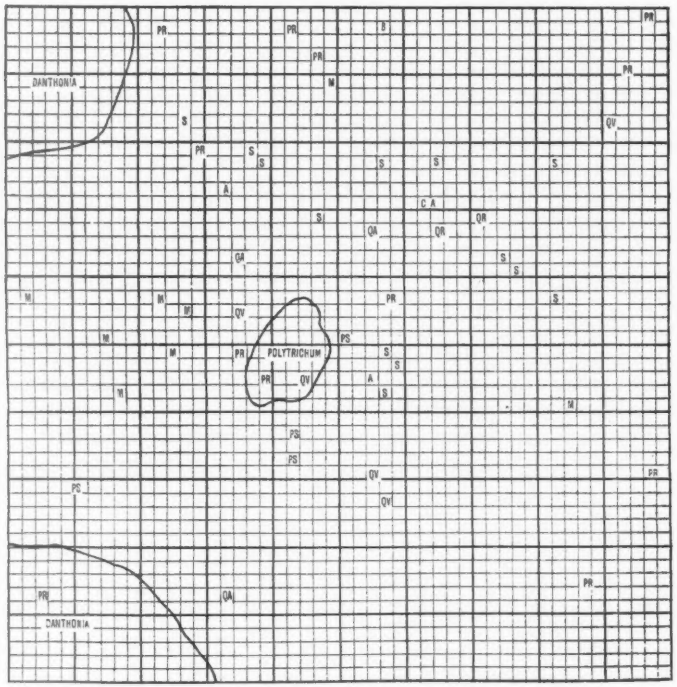


FIG. 6.—Sample plot 11. Pitch pine 25 years old in an old field, Colchester plain, 5 meters square; PR, *Pinus rigida* 12; QV, *Q. velutina* 7; QA, *Q. alba* 2; S, *Spiraea tomentosa* 12; A, *Acer rubrum* 2; B, *Betula populifolia* 1; M, *Myrica asplenifolia* 9; PS, *Pinus Strobus*.

old field on the Colchester plain has at 270^{m} from the seed trees 1 pitch pine and 6.3 white birch saplings on 25$^{sq\,m}$; at 170^{m} from the mother stand 3 pitch pine and 1.3 white birch; at 75^{m}, 7 pitch pine and no white birch on 25$^{sq\,m}$. In the second case the forest cover is complete and in the third case the stand is dense. At the greatest distance from the seed trees, the area between the birch and pine is

controlled by Myrica and Pteris. As the trees become more abundant these are gradually crowded out, until beneath the dense stand they disappear. The saplings nearest the seed trees are 25 years old and those farthest from the seed trees are 8 years old.

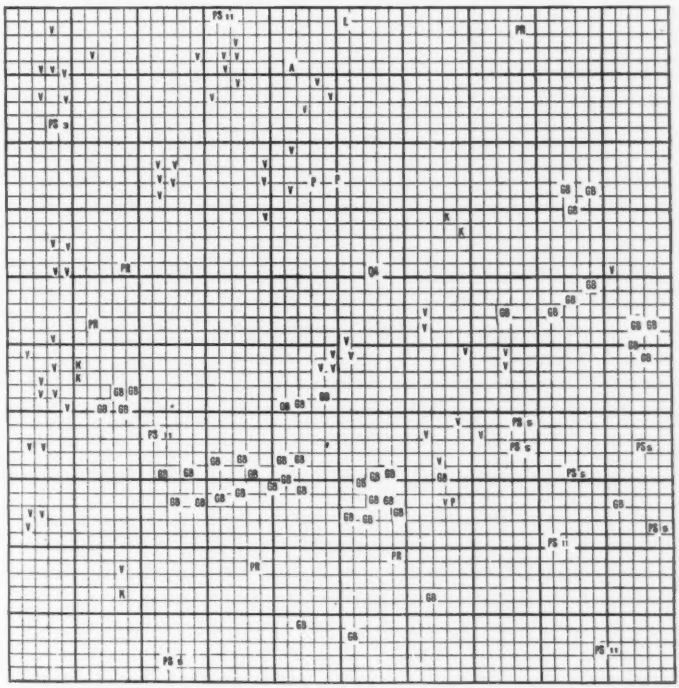


FIG. 7.—Sample plot 10. Pitch pine stand 60 years old, Colchester plain, 5 meters square; under layer, *Carex pennsylvanica*; PR, *Pinus rigida* 4; PS, *Pinus Strobus* 11; V, *Vaccinium vacillans* 59; GB, *Gaylussacia baccata* 44; K, *Kalmia angustifolia* 5; QA, *Q. alba* 1; L, *Lysimachia quadrifolia* 1; VP, *Vaccinium pennsylvanicum* 12; P, *Pteris aquilina* 26.

On p. 138 is given a sample plot (*fig. 6*) made in a stand of pitch pine 25 years old. Oaks are common in stands of this kind, but they are usually suppressed and apparently never become members of the dominant class.

An even-aged stand of pitch pine (36 years old on the stump)

on the Essex plain averages 6 trees on $25^{sq\,m}$. *Vaccinium pennsylvanicum* forms a carpet beneath, and growing up through this, one finds on the average square meter 13 Pteris, 5 *Gaylussacia baccata*, 14 *Melampyrum lineare*, 8 *Carex pennsylvanica*, 1 *Rubus alleghe-niensis*, 1 *Apocynum androsaemifolium*.

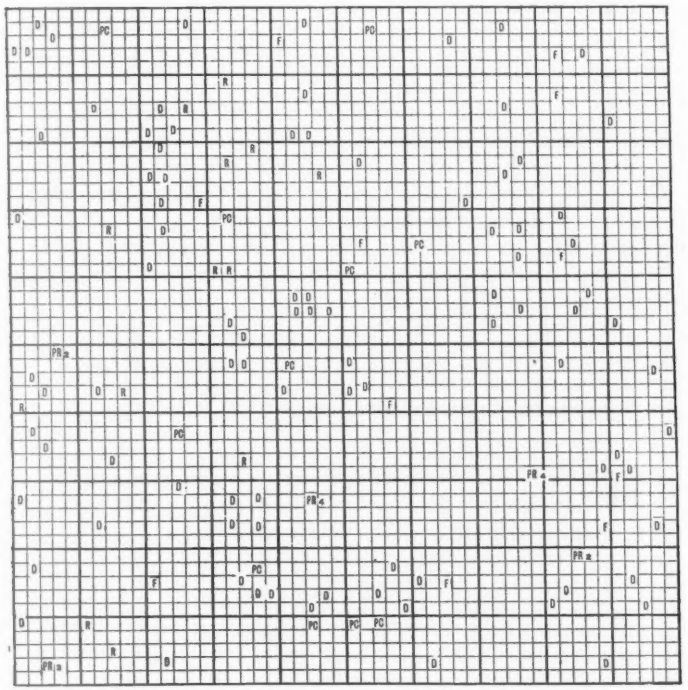


FIG. 8.—Sample plot 25. Danthonia-Polytrichum pasture being invaded by pitch pine; open patches occupied by Polytrichum; Colchester plain, 1 square meter; D, *Danthonia spicata* 89; R, *Rumex Acetosella* 13; F, *Fragaria virginiana* 10; PC, *Panicum capillare* 6; PR, *Pinus rigida* 2.

By the time pitch pine which has taken possession of the abandoned fields in the manner described above is 60 years old, the stand has become much less dense, averaging only one tree on $25^{sq\,m}$. The ground beneath is much less shaded and the soil is richer from the accumulation of humus. At this point white pine quite commonly

reproduces itself under the protection of the pitch pine, which is shown in the sample plot given on p. 140 (*fig. 7*).

3. SUCCESSION POSSESSING THE SOD-FORMING STAGE.—Many of the cultivated fields on the sand plains were "seeded down," bore crops of hay for a few years, and then were turned over to pasturage.

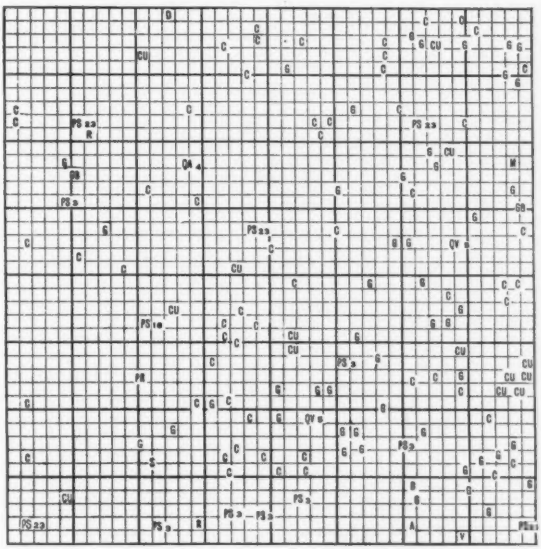


FIG. 9.—Permanent sample plot 35. Forty-year-old stand of pitch pine, Colchester plain, 4 meters square; PR, *Pinus rigida* 1; PS, *Pinus Strobus* 13; QV, *Q. velutina* 2; QA, *Q. alba*; C, *Carex pennsylvanica* 56; G, *Gaultheria procumbens* 46; CU, *Chimaphila umbellata* 11; GB, *Gaylussacia baccata* 2; D, *Diervilla Lonicera* 1; V, *Vaccinium vacillans* 1; B, *Betula populifolia* 1; A, *Acer rubrum* 1; R, *Rubus allegheniensis* 2; S, *Solidago* sp. 1.

Other fields formed a sod naturally without artificial seeding and were used as pastures. The chief sod-formers in this case were *Poa pratensis* and *Danthonia spicata*. After pastures formed in these two ways have been grazed for several years, they begin to lose their fertility. The first manifestation of this is the dying out of *Poa pratensis*, which is replaced by Danthonia. In course of time Danthonia gives way to *Polytrichum commune*. Most of the pastures

on the area under consideration are in the Danthonia-Polytrichum stage. The principal associated species are *Cyperus filiculmis, Panicum capillare, Spiraea tomentosa, Potentilla argentea, Solidago nemoralis, Rumex Acetosella, Aster linariifolius.*

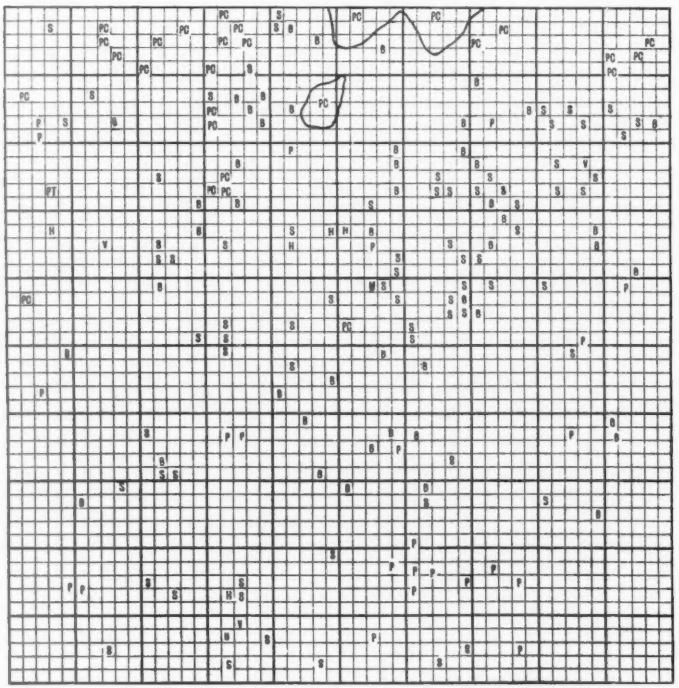


FIG. 10.—Sample plot 1. Danthonia-Polytrichum pasture, showing one-year-old white birch, Colchester plain, 1 square meter; B, *Betula populifolia* 49, at rate of 245 white birch on 25 square meters; S, *Spiraea tomentosa* 67; PC, *Poa compressa* 24; P, *Panicum capillare* 21; H, *Hypericum canadense* 5; V, *Verbena hastata* 3; PT, *Populus tremuloides* 1.

As in abandoned plowed fields, beds of Polytrichum are centers from which the tree invasion begins. As in the former case also, pitch pine and white birch are most commonly taking possession of worn-out pastures. Adjacent to mature pitch pine, pastures are transformed into pure even-aged stands of that species, while those

at a distance from the seed trees are eventually covered with uneven-aged stands, as described for old fields in the preceding section. Sample plot no. 25 (*fig. 8*) shows the character of a pasture in the first stages of possession by pitch pine.

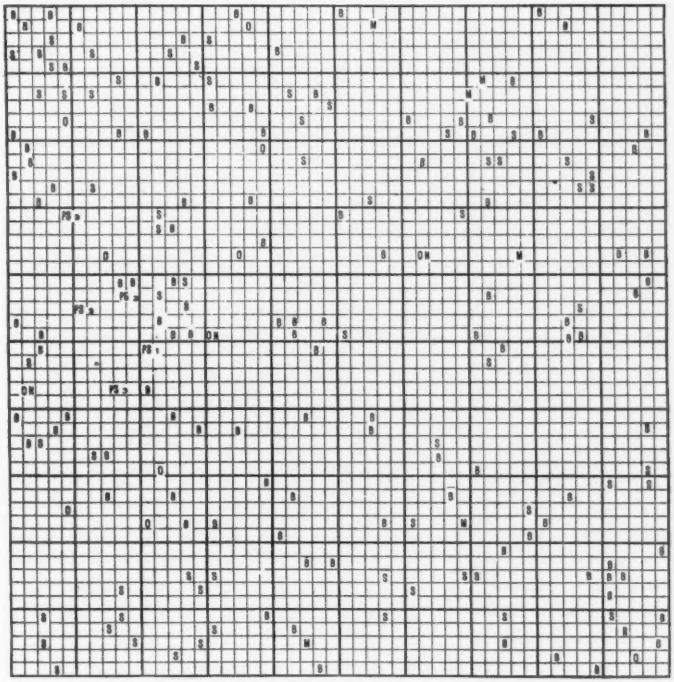


FIG. 11.—Sample plot 2. White birch 6 years old, pasture, Colchester plain, 5 meters square; a carpet of *Polytrichum commune* beneath; B, *Betula populifolia* 105; S, *Spiraea tomentosa* 64; O, *Osmunda cinnamomea* 8; M, *Myrica asplenifolia* 4; ON, *Onoclea sensibilis* 2; MU, *Monotropa uniflora* 2; R, *Rubus allegheniensis* 1; PS, *Pinus Strobus* 5.

Ten stands 5 to 15 years old averaged 34 trees on $25^{sq\,m}$, while ten stands 25 to 30 years old averaged 7 trees. The older stands of pitch pine show regeneration of white pine beneath them, and plots like no. 10 (*fig. 7*) may be commonly found in the old pastures as well as in the abandoned fields. In one case white pine seedlings and saplings

at the rate of 70 per $25^{sq\,m}$ were found beneath a 24-year old stand. There were 7.5 pitch pine on $25^{sq\,m}$. Unfortunately these stands are periodically burned and the seedlings are killed, so there is little opportunity of observing the older stages of this undergrowth of white pine. On the Macomber lot, however, where fire has been rigorously

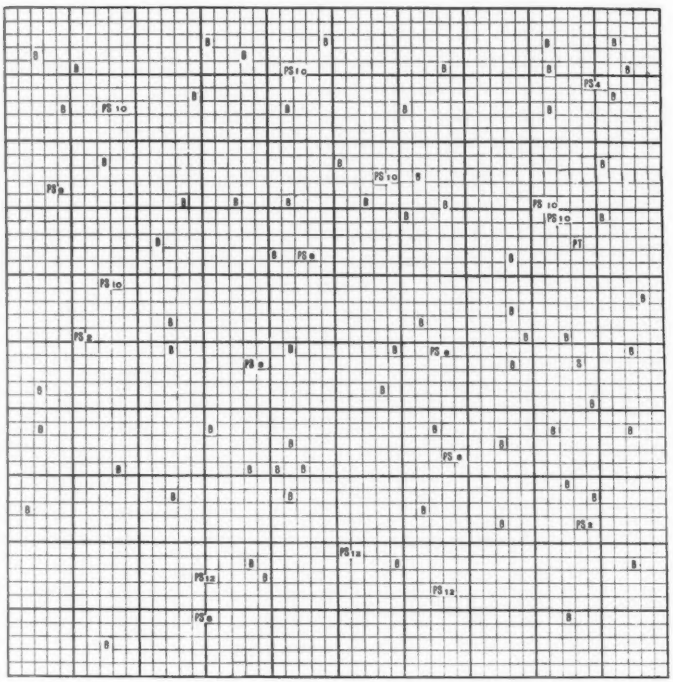


FIG. 12.—Sample plot 9. White birch 15 years old, Colchester plain, 5 meters square; under layer, Polytrichum, *Onoclea sensibilis, Rubus hispidus;* B, *Betula populifolia* 68; PS, *Pinus Strobus* 18; PT, *Populus tremuloides* 1; S, *Spiraea tomentosa* 1.

excluded for many years, one may find the older stages. Sample plot 35 (*fig. 9*) shows white pine 23 years old beneath pitch pine 40 years old. There is little doubt of the ultimate control of such pitch pine stands by white pine, were forest fires excluded.

White birch in the old pastures usually forms dense pure stands. The series of stands shown in *figs. 10–13* illustrates displacement of

white birch by white pine. It will be noted that the numbers of white birch on the unit area for the ages given are 245, 105, 68, and 16; and that the numbers of white pine increase as follows: 0, 5, 18, 46. This illustrates the most striking fact in the course of succession on worn-out pastures, that is, gradual replacement of white birch by

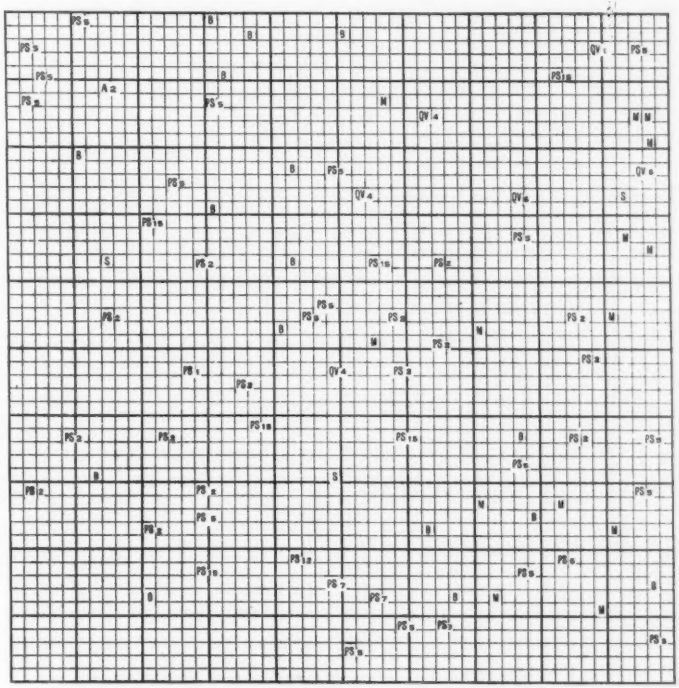


FIG. 13.—Sample plot 17. White birch 25 years old, 5 meters square, 50m from white pine; under layer Polytrichum and *Rubus hispidus;* B, *Betula populifolia* 16; PS, *Pinus Strobus* 16; QV, *Quercus velutina* 6; M, *Myrica asplenifolia* 14; S, *Spiraea tomentosa* 3; A, *Acer rubrum* 1.

white pine. If a stand of white birch is within proper distance from white pine seed trees, the birch acts as a nurse tree to the pine.

In the clearing of the sand plains occasional white pine trees were left along the margins of wood lots and along highways. Such trees became the originators of numerous pure stands of white pine in the

old pastures. Sample plot no. 37 (*fig. 14*) gives the character of the pasture when the white pine invasion begins.

Stands of all ages occur from the seedling stage to mature trees. As in the case of pitch pine, one may find patches of white pine con-

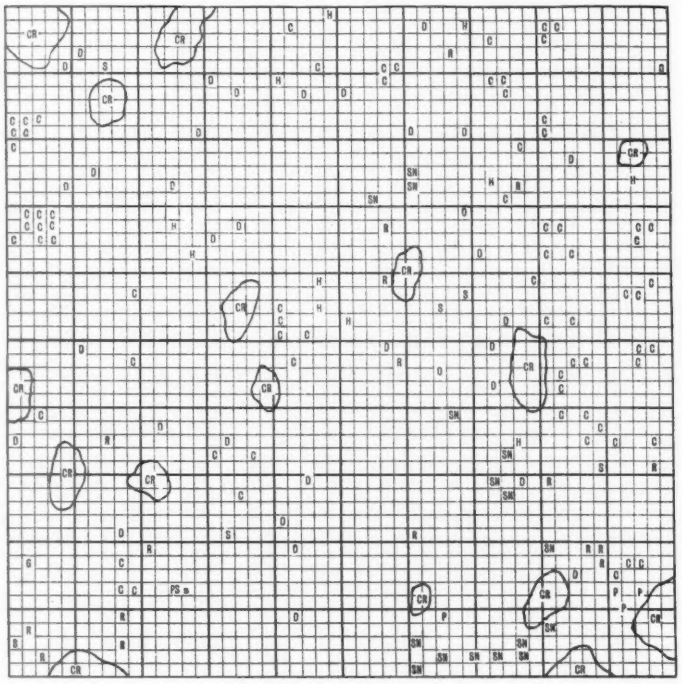


FIG. 14.—Sample plot 37. Pasture being invaded by the white pine, Colchester plain, 1 square meter; C, *Cyperus filiculmis* 72; D, *Danthonia spicata* 34; R, *Rumex Acetosella* 16; SN, *Solidago nemoralis* 14; H, *Hypericum canadense* 10; S, *Spiraea tomentosa* 6; P, *Panicum capillare* 4; CR, *Cladonia rangiferа;* G, *Gnaphalium polycephalum* 1.

taining three generations of trees, each generation even-aged and in pure stand. The stands now in the process of installation offer a good opportunity to study the abundance of seedlings in relation to the distance from the mother tree. For example, the number of seedlings were counted on plots 5^m square with the following results: 30 to 25^m

from the seed tree, 4 seedlings; 25 to 20^{m}, 17 seedlings; 20 to 15^{m}, 24 seedlings; 15 to 10^{m}, 25 seedlings; 10 to 5^{m}, 35 seedlings; 5–1^{m} from a vertical line dropped from the outer margin of the crown of the seed tree, 85 seedlings. The seedlings were 3 and 8 years old.

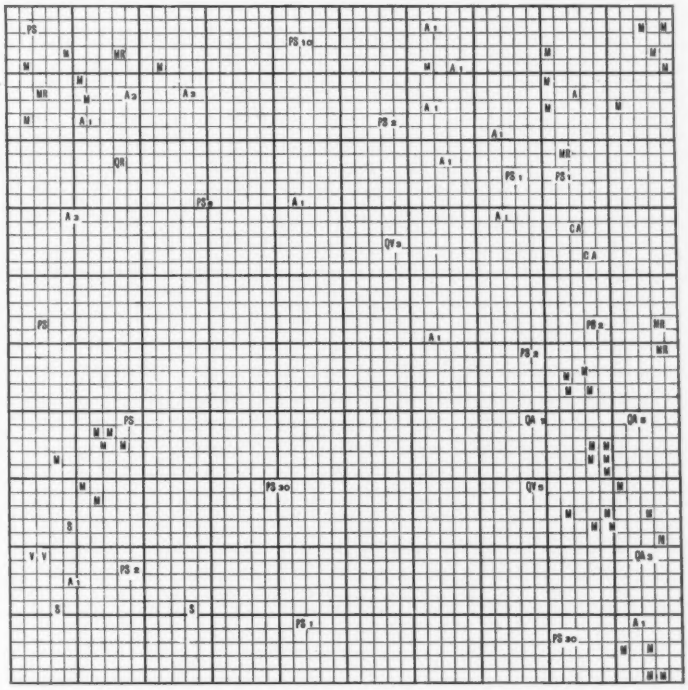


FIG. 15.—Sample plot 13. White pine stand 35 years old, an abandoned cultivated field, Essex plain, 5 meters square; PS, *Pinus Strobus* 14; QV, *Q. velutina* 2; QA, *Q. alba* 1; QR, *Q. rubra* 1; A, *Acer rubrum* 14; CA, *Corylus americana* 2; M, *Maianthemum canadense* 35; MR, *Mitchella repens* 5; V, *Vaccinium vacillans* 1; S, *Solidago* sp. (rosette) 3.

During their sapling stage the pure stands of white pine are usually so dense as to exclude secondary vegetation, but by the time they are 30 years old they have become thinned out sufficiently to allow undergrowth. This is illustrated in sample plot no. 13 (*fig. 15*), made beneath a stand 35 years old. Seedling and sapling oaks are of com-

mon occurrence beneath the older white pine in sufficient numbers to indicate an eventually mixed stand should they persist.

In the discussion of succession on abandoned fields it has been shown that white pine is gradually regaining control of the areas on which it was once dominant, by the direct reseeding leading to the establishment of pure stands, indirectly by the supplanting of white birch stands, and, were human interference withdrawn, by the replacement of pitch pine stands.

I have employed the month of vacation for the past six years in the study of the sand plain vegetation. Forty-five permanent sample plots in the stands, representing various stages of succession, have been established and mapped, and those have been given above which in my judgment best represent the conditions discussed. Most of these plots will be kept under observation in the future, so that definite records of the changes *in situ* may be recorded. Besides these, the character of the vegetation has been recorded by 100 list charts.

While investigations have been conducted in the effort to determine what changes in ecological conditions have brought about the changes in vegetation on the sand plains, I feel that they have not progressed far enough to justify their publication. Therefore it seemed best to make the present paper simply a record of succession. The nomenclature is that of GRAY'S *New manual of botany*.

Summary

Pitch pine succeeded to the control of areas from which the dominant white pine had been removed.

White pine, however, is gradually regaining its control on cut-over areas, as well as on abandoned fields, by its actual replacement of white birch stands and by its probable displacement of the pitch pine stands.

The work upon this paper was begun at the suggestion of Dr. L. R. JONES of the University of Vermont and was continued under Dr. H. C. COWLES of the University of Chicago. I wish to express my appreciation of the kindly criticism and encouragement received from them.

UNIVERSITY OF TORONTO

CURRENT LITERATURE

BOOK REVIEWS

The genera of fungi

Several years ago Professor CLEMENTS began a translation of the keys to the genera of fungi in the original eight volumes of SACCARDO'S *Sylloge Fungorum*, and this has now resulted in a book.[1] With the appearance of a large number of new genera in the subsequent volumes, the keys have been arranged on an entirely different plan from that found in the *Sylloge*, although the spore sections based on the color, shape, and septation of the spores have been retained. In the case of certain groups, the arrangement differs from that found in the *Sylloge*, as well as from that generally followed; for example, the bacteria are included among the Phycomycetes, the Uredinales and Ustilaginales among the Ascomycetes. The reviewer has taken some pains to test certain portions of the key. In most of the cases tried, one would have been led astray, unless the plant were already known, and even then, were the key followed literally, the plant would often reach the wrong genus, if not the wrong group. For example, the first two paragraphs in the key are supposed to enable the student to determine whether a plant belongs in the Phycomycetes or in the second division. If the plant to be named is a Peziza, and if the student knows it is an ascomycete, he would not need the key; but if he did not know this, he would certainly place it in the Phycomycetes if he depended on the words of the key, having in mind the structures usually present in the perfect fruit body of an ascomycete. On examining a teleutospore, or other spore form of the Uredinales or Ustilaginales, who would recognize it as an ascus, or any structure in these orders as an ascomycetous structure, unless he already knew it? One must have a good knowledge of fungi before a key of this kind becomes very useful, and then the keys to the general subdivisions would not be necessary. Diagnostic characters for the general subdivisions would be more helpful. In this respect SACCARDO'S keys to the genera are useful, since they are at the same time diagnostic.

A few of the inaccuracies may be mentioned. The key to the Myxobacteriaceae (p. 8) is incorrect in the statement "cells finally forming rows of globose spores" in Myxococcus, since each rodlike cell forms a single spore (see THAXTER, BOT. GAZETTE **23**:400. 1897). The key to the Cladochytriae is incorrect, since there are species which possess both resting sporangia and zoosporangia. Not all the Syncephalidae form zygospores above conjugating progametes, as stated in the key, even in Piptocephalis. The key further says

[1] CLEMENTS, FREDERIC EDWARD, The genera of fungi. 8vo. pp. 227. Minneapolis: The H. W. Wilson Company. 1909.

"conidia in chains." The spores are borne in sporangial filaments (see THAXTER, BOT. GAZETTE **24**:1–15. 1897). In Leptomitae there is a confusion of distinctions. "Naegeliella" should be Sapromyces (see FRITSCH, Oesterr. Bot. Zeits. **43**:420. 1893). Araiospora of THAXTER is changed to "Araeospora," whether by a typographical error or because of "faulty composition," we are not told. Gonopodya and Myrioblepharis are incorrectly placed in the Monoblepharidaceae; the former is leptomitaceous, while the latter is pythiaceous. The genus Diblepharis does not exist (see THAXTER, Rhodora **5**:103. 1903); and so on. Some of the good genera omitted from the higher Phycomycetes are Cunninghamella, Thamnocephalis, Zygorhynchus, Proabsidia, Lichtheimia, Mycocladus, Tieghemella, Sapromyces, etc. The author has revised THAXTER'S arrangement of the Laboulbeniales, and one of the first things to be noticed is that Stichomyces, with simple antheridia, is placed in the group which is characterized by compound antheridia.

"Subfamily Harpochytriae" on p. 11, and "Harpochytrium" as one of the genera is probably a slip for Hyphochytriaceae and Hyphochytrium. On p. 47 something seems to be omitted after the line "Stroma on a white subicle," unless it indicates a hypothetical group.

Although the author says that "questions of nomenclature have been left largely to one side," a large number of new names are proposed for genera, in many cases as substitute names for already existing valid ones. For example, where a generic name is longer than the author thinks it should be, he shortens it; Dimerosporopsis is changed to Dimerosporis, Trematosphaeriopsis to Trematosphaeris, Hyalethyridium to Hyalothyris, Gymnoascus to Gymnascus, Exoascus to Exascus, etc. Objection is made also to the use of generic names of "faulty composition," and many names are changed to conform to an adopted standard of word-formation; thus, Tremellopsis is changed to Tremellastrum, Coleopuccinia to Coleoma, Oscarbrefeldia to Ascodes, Podosordaria to Pedisordaria, Aureobasidium to Chrysobasidium, etc., while Tremellodon, for example, is allowed to stand. It may be admitted that authors of long generic names should have selected shorter ones, and should have used greater care in word-formation, but if we recognize CLEMENTS'S principles of nomenclature, we must accept them from anyone who chooses to change the spelling of genera or to substitute new generic names for any of the present valid ones. It requires very little imagination to foresee the result of such a policy. The object in adopting principles of botanical nomenclature is to secure as uniform methods in naming plants as possible. The name is merely a medium of exchange by which we convey to others the concept of the organism with which we are dealing, and a name employed in accordance with principles adopted by an international representative assembly of botanists is more useful than an invalid name.

Besides the large number of arbitrary changes in generic names, a large number of new generic names are proposed without any diagnosis other than the few differential words used in the key. Some have a better basis, perhaps, than others. Two which were examined at random will show on what very insufficient

grounds some of them, at least, are founded. *Iotidea* is proposed as a genus for *Otidea pleurota* (Phillips) Rehm (*Peziza pleurota* Phill.) on the ground that the tips of the asci are stained blue with iodin, while in the other species of Otidea (in the sense of REHM, Rabenh. Krypt. Fl. Pilze **3**:1023. 1896) the ascus usually is not stained blue with iodin. By students of the Discomycetes this character is regarded at most merely as a specific character, and some of our best students (including PHILLIPS) regard it as a variable one and do not place great stress upon it as a crucial test of specific difference.[2] *Belospora* is proposed as a genus for *Belonioscypha ciliatospora* (Fuckel) Rehm, *ibid.* 744 (*Ciboria ciliatospora* Fuckel), on the ground of the presence of a cilium at each end of the spore. Later REHM (*ibid.* 1267) says that BRESADOLA justly regards this species as only a young form of *Helotium scutula*, the cilia soon disappearing and the spores becoming divided.

Quite a number of genera have been included in others, but this is done "only for the sake of the beginner, when the descriptions reveal no differences." In some of the genera so treated the differences indicated are certainly greater than those on which some of the new genera are based. Lloydiella, for example, is included in Hymenochaete, although the differences are clearly indicated. Whether Lloydiella is a valid genus may be questioned, but it certainly does not bear so close a relationship to Hymenochaete as it does to Stereum, on certain species of which it was based because of the presence of hyaline cystidia, while Hymenochaete possesses colored setae.

There is a convenience in having the genera in all of the volumes of SACCARDO'S *Sylloge* brought together for reference. The glossary of Latin and English terms, covering 28 pages, will be of great value to students using SACCARDO's work, who have not a good command of Latin.—GEO. F. ATKINSON.

A new laboratory manual

FRYE and RIGG have met their local needs, and perhaps more general needs as well, by the publication of a laboratory manual.[3] The outlines are the outcome of a test of two years, and they are now being used in the university with students who have not had botany in high school. Both authors have had experience in high schools, and should be able to judge what is suited to high-school pupils; both have been students of the botany of the northwest for some years, and should know what material is to be recommended for elementary classes.

The course is divided into two parts: the vegetative organs of vascular plants, and types of the larger groups of plants. The first section treats of leaves, stems, roots, seeds, and the relation of plants to their environment; while in the second the usual four groups are presented. In the first four topics of the first section the exercises are those usually found in this connection, but in the last one there

[2] See COOKE, M. C., Observations on *Peziza calycina*. Grev. **4**:169–172. 1876.

[3] FRYE, T. C., AND RIGG, GEO. B., Laboratory exercises in elementary botany based on the plants of the Pacific Northwest. pp. 75. Seattle: University Book Store. 1909.

is a distinct change in treatment. Instead of taking the typical ecological regions, a representative plant from each region is made the basis of study. The plants used are cactus (xerophyte), bladderwort (hydrophyte), Salicornia (xerophytic hydrophyte), and dodder (a parasite). Such treatment doubtless has distinct advantages, since the beginning student organizes data much more readily around an individual than around such abstractions as hydrophytes, xerophytes, etc. Some may question whether this really gives an adequate presentation of the great ecological divisions, but probably the authors would answer that it is better to have beginners get a definite idea about a few representative plants, than a somewhat hazy idea about a number of plants and definite notions about none of them. When ecology was first introduced into courses of study, it was heralded by some as a means of breaking away from the regulation type study method, and it is especially interesting in this connection to see ecology adopting the type study as the best means of presenting its data to beginners.

The exercises are fairly well written. Each begins with a definite statement of the purpose, and of the materials and apparatus needed for it. The directions for observation and study are very general, but in the hands of a good teacher such directions will stimulate good habits of laboratory study; indeed it seems quite undesirable to attempt to arrange a manual that will not require the presence of a good teacher, since the personal contact of such a teacher is the most important factor in the course.—O. W. CALDWELL.

MINOR NOTICES

A new lilac disease.—KLEBAHN[4] has described briefly the more common fungi found on lilacs used for winter forcing in Europe. The greater part of the paper is devoted to a new disease caused by *Phytophthora Syringae*. The fungus infects the twigs of the lilac plants, killing them over a distance of several internodes. Usually the upper internodes are killed, but often parts of the stems lower down are killed. The flower buds on the infected twigs do not develop, so that only leafy shoots are produced from lower uninjured buds. Since the value of a forcing lilac depends largely on the symmetry of the plants and the even distribution of the flowers, great loss is caused by the damage of a few twigs, especially since the injury is not detected until the plants are started into growth. It appears that the greater part of the infection occurs while the plants are in storage. After they are dug up in the fall, it is customary to heel them in in cold frames so that one side of the plants is in contact with the ground. Both observation and experiment showed that it is through contact with the earth that the twigs become infected.

A somewhat lengthy account is given of the characters and biological behavior of the fungus. In the lilac twigs and buds only oospores were found, which led to a former publication describing the fungus as *Ploeophthora Syringae*. In this

[4] KLEBAHN, H., Krankheiten des Flieders. pp. 75. *figs.* 45. Berlin: Gebrüder Borntraeger. 1909.

investigation the author succeeded in growing the fungus in pure cultures, and thus obtained sporangia belonging to the genus Phytophthora. By means of zoospores, not only lilacs but also a number of other plants were infected, showing close relationship of the fungus to *Phytophthora omnivora* DeBary. The relationship is discussed at length, and although the author is somewhat doubtful in his conclusion, he is inclined to regard the fungus as a species (*P. Syringae*) differing slightly in morphological and biological characteristics from DeBary's *P. omnivora*.—H. Hasselbring.

The problems of life.—In 1900 Giglio-Tos published the first part of his work under this title.[5] The general thesis of the book is that vital phenomena are all referable to relatively simple fundamental causes, and in the first part there is an attempt to set forth a logical and consistent hypothesis of the organization of protoplasm and its fundamental functions. The second part appeared in 1903,[6] and applied the same method to the phenomena of ontogeny. In 1905 the third part was published,[7] extending the author's hypothesis to the phenomena of fertilization and heredity. Now the fourth and last part has appeared,[8] and reduces to relative simplicity the important problems of variation and the origin of species. The theory of the whole book begins with an assumption regarding the molecular structure of protoplasm and the nature of assimilation, and applies this assumption by a logical series of deductions to the most fundamental problems of biology. The logic may be good, but it cannot transform the assumption, interesting as it may be, into a fact. Even a fact is influential only in its own immediate neighborhood, and the author has traveled far beyond the region where an initial fact, much less an assumption, can be serviceable.—J. M. C.

A new flora of California.—Two parts of *A flora of California* by Jepson[9] have been published recently. Part I contains the families Pinaceae to Taxaceae and Part II the Salicaceae to Urticaceae inclusive. The text is printed in carefully selected type which differentiates admirably the subject matter on the page. The descriptions, while full and accurate, are not overtechnical; the bibliography and synonomy are presented in sufficient detail to give a ready understanding without being cumbersome, and particular emphasis is given to the geographical distribution of species and varieties. Several well reproduced photographs and numerous original figures materially supplement the text. New species are described in Cupressus and Quercus. The publication happily combines scientific accuracy

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[5] Review in Bot. Gazette **31**:275. 1901.

[6] *Ibid.* **37**:151. 1904.

[7] *Ibid.* **41**:450. 1909.

[8] Giglio-Tos, Ermanno, Les problèmes de la vie. IV^e^ partie: La variation et l'origine des espèces. 8vo. pp. vii+222. Cagliari: The author, at the University. 1910. *fr.* 8.

[9] Jepson, W. L., A flora of California. Royal 8vo. Part I, pp. 33–64. *figs. 13;* Part II, pp. 337–368. *figs. 5.* San Francisco: Cunningham, Curtiss, and Welch. 1909.

with simplicity of description, and its appearance is most gratifying to those interested in the Pacific coast flora. It is earnestly hoped that the work may continue to completion.—J. M. GREENMAN.

NOTES FOR STUDENTS

Current taxonomic literature.—J. C. ARTHUR (Mycologia 1:225–256. 1909) under the title "Cultures in Uredineae in 1908" has published new species in Puccinia and Gymnosporangium; this article is the ninth in a series of reports on the culture of plant rusts.—O. BECCARI (Leafl. Philipp. Bot. 2:639–650. 1909) in an article entitled "New or little known Philippine palms" describes four new species.—V. F. BROTHERUS (*ibid.* 651–658) has published 11 new species of mosses from the Philippine Islands.—C. BERNARD (Dept. Agr. Ind. Néerland. pp. 1–94. *pls. 1–6.* 1909) in a paper entitled "Sur quelques algues unicellulaires d'eau douce récoltées le Domaine Malais" has described several new species and varieties of unicellular algae and proposes a new genus (*Spinoclosterium*).—R. C. BENEDICT (Bull. Torr. Bot. Club **36**:463–476. 1909) presents a provisional revision of the genus Ceratopteris and includes one new species (*C. deltoidea*) from Jamaica.—B. T. BUTLER (*ibid.* 421–440) gives a synopsis of the west American birches in which 17 species are recognized, 7 being indicated as new; a key precedes the characterization of species.—L. CLARK (*ibid.* 299–307. *pl. 20*) under the title "Some noteworthy Hepaticae from the state of Washington" includes a new species of Jungermannia and a new variety of *Scapania paludosa* C. Müll. Frib.—W. W. EGGLESTON (*ibid.* 501–514) in an article entitled "The Crataegi of Mexico and Central America" describes 4 new species and 2 new varieties.—H. D. HOUSE (*ibid.* 595–603) in continuation of his studies in the Convolvulaceae gives a synoptical revision of the genus Quamoclit in which 8 species are recognized, one being new to science.—R. H. HOWE, Jr. (*ibid.* 309–326. *pls. 21–23*) presents an interesting article dealing with the genus Usnea as represented in New England. The text is supplemented by maps showing the distribution of species and forms occurring in that section.—E. A. MCGREGOR (*ibid.* 605–609) describes and illustrates two new spermatophytes from California.—K. K. MACKENZIE (*ibid.* 477–484) in continuation of his studies in the genus Carex has described 8 new North American species.—E. L. MORRIS (*ibid.* 515–530) in a third paper on "North American Plantaginaceae" treats in detail several technical species and proposes two new specific names.—P. A. RYDBERG (*ibid.* 531–541) under "Studies on the Rocky Mountain flora XIX" describes several new species of Gramineae.—R. E. STONE (*ibid.* 549–552) describes a new species of Puccinia which was found growing on *Rynchospora corniculata* (Lam.) Gray at Auburn, Alabama.—C. H. PECK (*ibid.* 329–339) describes 22 new species of fungi from different parts of the United States; the same author (N. Y. State Mus. Bull. 131. pp. 18–58. 1909) describes new species of American fungi, several being illustrated.—Q. BORGE (Arkiv för Botanik **8**: no. 13. pp. 29. *pl. 1.* 1909) under the title "Nordamerikanische Süsswasseralgen" describes and illus-

trates a new species of Closterium and a new variety of *Cosmarium cuneatum* from Florida, aso a new species of Anabaena from Lower California.—R. E. FRIES (*ibid.* no. 8. pp. 51. *pls. 1, 2*) has published 6 new species of flowering plants collected along the boundary between Bolivia and Argentina; the same author (*ibid.* no. 11. pp. 34. *pls. 1–4*) describes and illustrates several new Gasteromycetes from the same region.—G. O. MALME (*ibid.* no. 1. pp. 30. *pl. 1*) presents a synoptical revision of the South American genera Araujia and Morremia and describes a new species in the latter genus.—N. SYLVEN (*ibid.* no. 6. pp. 48. *pls. 1–7*) gives an account of the South American species of Genlisea and Utricularia, based on material in the Regnell herbarium. Four species of the former genus are recorded, of which one from Minas Geraës is new; and in Utricularia 34 species are recorded, 9 of which are new to science.—E. WAINIO (*ibid.* no. 4. pp. 175) under the title "Lichenes in viciniis hibernae expeditionis Vegae prope pagum Pitlekai in Siberia septentrionali a D:re E. Almquist collecti" has published several new species belonging to different genera and proposes a new genus (*Melanaspicilia*) to which six species are referred.—N. L. BRITTON (Torreya **9**:153–160. 1909) gives an account of the genus "Rhipsalis in the West Indies," recording three species, one of which (*R. jamaicensis*) is new.—T. D. A. COCKERELL (*ibid.* 166, 167) proposes a new generic name (*Wedeliella*) for a certain group of nyctaginaceous plants; the type of the genus is *Allionia incarnata* L.—G. V. NASH (*ibid.* 209, 210) records a new species of Danthonia from Jamaica.—H. CHRIST (Bull. Acad. Int. Geo. Bot. **18**:146–178. 1909) under the title "Fougères d'extrême Orient" has published several new speeies of ferns from Korea, Sachalin, and China.—H. LÉVEILLÉ (*ibid.* 1–138) presents a synopsis of the Chinese and Japanese species of Rubus; the author recognizes 143 species for China and 48 for Japan. The descriptions of species are preceded by a determinative key, of which the character of the leaves and the presence or absence of spines form the primary basis for division.—E. VANIOT and H. LÉVEILLÉ (*ibid.* 139–145) have published 18 new species of Compositae from Korea, 12 of which belong to the genus Aster.—C. CHRISTENSEN (Smiths. Misc. Coll. **52**:365–396. 1909) in an article entitled "The American ferns of the group of *Dryopteris opposita* contained in the U. S. National Museum" presents critical notes on several species and publishes 9 species and 3 varieties of this genus as new to science.—F. FEDDE (Rep. Nov. Sp. **7**:255–257. 1909) describes 4 new varieties of *Papaver nudicaule* L., 3 of these being from the Rocky Mountain region.—A. LINGELSHEIM, F. PAX, and H. WINKLER (*ibid.* 241–251) in continuation of their studies on the Bolivian flora have published 22 new species of dicotyledonous plants.—K. WOLFF (*ibid.* 274–279) under the title "Species novae generis Eryngii Americae centralis et australis" has published 6 species new to science.—E. L. GREENE (*ibid.* 252–255) describes 8 new species of Thalictrum, chiefly from western North America; the same author (Midland Naturalist **1**:99–104. 1909) has published 3 new species of Thalictrum from North Dakota.—A. A. HELLER (Muhlenbergia **5**:133–143. 1909) publishes the first of a series of articles on the "Nevada lupines"; the

sections *Lupinellus* and *Platycarpos* are here treated, and one new species is proposed.—E. GILG and R. MUSCHLER (Bot. Jahrb. **42**:437–487. 1909) in an article entitled "Aufzählung aller zur Zeit bekannten südamerikanischen Cruciferen" have published 19 new species and have made several new combinations. The following new genera are proposed: *Sarcodraba* (1 species), based on *Draba karraikensis* Speg.; *Aschersoniodoxa* (2 species), based on *Draba Mandoniana* Wedd.; *Weberbauera* (1 species), based on *Braya densiflora* Musch.; and *Brayopsis* (9 species), based on *Eudema grandiflora* Planch.—W. HERTER (Allg. Bot. Zeits. **15**:129. 1909) has publlshed a new species of Ibatia from Uruguay.—J. HUBER (Bull. Soc. Bot. Genève II. **1**:245–249. 1909) describes and illustrates two new species of Ericaceae from the plains of the Amazon.—L. KRAUTER (Contr. Bot. Lab. Univ Penn. **3**:93–206. 1908) gives a synoptical revision of the genus Pentstemon, recognizing 148 species and numerous varieties.—R. E. KUNZE (Monats. Kakteenk. **19**:149, 150. 1909) describes and illustrates a new species of Echinocactus (*E. arizonicus*) from Arizona.—J. A. PURPUS (*ibid.* 133, 134) describes a new species of Opuntia from Utah; the description is accompanied by an illustration.—L. QUEHL (*ibid.* 155, 156) has published a new species of Mamillaria (*M. ceratites*) from Mexico.—W. WEINGART (*ibid.* 150–155) publishes a new species of Cereus (*C. Purpusii*) which is indigenous to western Mexico.—R. G. LEAVITT (Phil. Journ. Sci. Botany **4**:201–245. 1909) under the title "The genus Eria in the Philippine Islands" recognizes 40 species, 13 being described for the first time. A synoptical treatment with several text figures follows the Latin diagnoses of species.—E. D. MERRILL (*ibid.* 247–330) in continuation of his studies on the flora of the Philippines has pubished 83 new species of flowering plants and proposes the following new genera: *Embolanthera* of the Hamamelidaceae, *Everettiodendron* of the Euphorbiaceae, *Ahernia* of the Flacourtiaceae, and *Greeniopsis* of the Rubiaceae.—C. B. ROBINSON (*ibid.* 331–407) gives a "Preliminary revision of the Philippine Myrtaceae." Of the 10 genera recognized 7 are monotypic, 2 contain 2 species each, and one, Eugenia, is represented by 98 species, of which 62 are described as new to science.—C. F. MILLSPAUGH (Field Col. Mus. Bot. Ser. **2**:289–321. 1909) in continuation of his studies on the flora of the Bahamas has published 12 new species of dicotyledonous plants, proposes a new genus (*Euphorbiodendron*) of the Euphorbiaceae, and makes several new combinations.—A. PASCHER (Oesterr. Bot. Zeitschr. **59**:329–331. 1909) has published a new genus (*Atropanthe*) of the Solanaceae from China.—A. ZAHLBRUCKNER (*ibid.* 349–354) in pursuance of his studies on the lichen flora of Dalmatia describes several new species and characterizes a new genus (*Agonimia*), based on *Polyblastis tristicula* Th. Fr.; the same author (Ann. Mycol. **7**:472–478. 1909) under the title "Neue Flechten V" has published several new species of lichens of which 4 species and one variety are from Florida and Arizona.—R. A. ROLFE (Kew. Bull. 268–277. 1909) gives a "Revision of the genus Cycnoches," enumerating 16 species mostly native in Central and South America.—T. A. SPRAGUE (*ibid.* 264) describes a new species of Phyllanthus from Mexico.—J. M. GREENMAN.

Theory of individual development.—In a Darwin Anniversary address given at the University of Chicago and now published,[10] LILLIE analyzes organic development and the theories relating to it in an unusually clear and satisfactory way. He calls attention to the fact that ontogeny and phylogeny are not two separate and distinct series of phenomena, and that individual development is not something distinct from evolution, but is a part of the process of evolution. In fact, we have no actual experience of any other form of development than individual development, racial development being an inference from innumerable facts. The development of the individual is a series of processes, capable of resolution into simpler biological processes, and these presumably into physico-chemical events. Such attempted analyses come under the head of physiology of development, a method of attack known in Germany as developmental mechanics. Under this head the author discusses embryonic primordia and the law of genetic restriction, the principle of organization, the rôle of cell division in development, and environment.

The presentation of the last topic is especially suggestive, both extra-organic and intra-organic environment being recognized. The former needs no definition; the latter may be defined by the statement that each part of a developing embryo has an environment consisting of all the other parts, some of which constitute relatively immediate environmental factors, others relatively remote ones. Examples of experiments are given to illustrate the influence of intra-organic environment on development, which also show that an immense part of what is called inheritance is inheritance of environment only, that is, repetition of similar developmental processes under similar conditions. It is stated that we are driven to the conclusion that the apparent simplicity of the germ is real; that the germ contains no gemmules, or determinants, or other representative particles; that development is truly epigenetic, a natural series of events that succeed one another according to physico-chemical and physiological laws; and that the explanation of the sequence consists simply in the discovery of each of its steps.

The author discusses certain applications of this point of view, and shows that such biological conceptions as the inheritance of acquired characters, atavism, and unit characters are inconsistent with it, special attention being given to the last because it is essentially modern and has many adherents. The analysis of the term "character" is very effective, the term having been prescribed by taxonomists and meaning any definable feature of an anatomical kind that differentiates species. The study of the physiology of development shows that whatever else "characters" may be, they are not units; "they simply represent the sum of all physiological processes coming to expression in definable areas or ways." *Character* is essentially a static morphological term; in the study of heredity and development we are dealing with biological *processes*.

The general conclusion is that the theory of individual development must

[10] LILLIE, FRANK R., The theory of individual development. Popular Science Monthly **75**:239–252. 1909.

more and more come to be regarded as a branch of physiology proper. The theory of representative particles must be relegated to the class of formal hypotheses whose usefulness is largely outlived; and while it may still play a part in speculations on heredity, the author believes that it will come to be generally recognized by those who use it as a mere matter of convenience of terminology, and not as an explanation of the phenomena described in its terms.—J. M. C.

The rôle of glucosides.—WEEVERS continues his researches on the glucosides of plants, with investigations of arbutin and salicin, and their allies.[11] He reports that both are to be considered as reserve foods, the combination of benzol derivatives with glucose serving to form compounds of low diffusibility, and therefore suitable for the accumulation of sugar in the cells. Arbutin in *Vaccinium Vitis-idaea* is localized in the leaves, and is used in the spring when the shoots develop, being split by an enzyme into glucose and hydrochinon. The latter remains in the leaves and is used again to combine with the glucose formed by photosynthesis, none being free in autumn. *Pirus communis* contains a glucoside which is probably identical with arbutin, and behaves in the same way. In *Salix purpurea* and *Populus monilifera* there appears to be a complex of enzymes, of which one, salicase, splits salicin into saligenol and glucose; another, saligenase, destroys saligenol and produces catechol; and a third breaks up catechol, forming a black amorphous insoluble pigment. This catecholase, however, gets at catechol only on decay of the tissues. All summer, salicin is formed daily in the leaves; nightly it is hydrolyzed and the glucose is carried away to the cortex. When in autumn the salicin content of the cortex approaches that of the leaves, this process stops. Populin is another product common to the two genera, but more variable in behavior. Populase forms catechol from it also.—C. R. B.

Hindi cotton.—COOK[12] has published a statement in reference to Hindi cotton, the interest of which extends beyond the immediate cultural problem. The name is applied in Egypt to an undesirable type of cotton that injures the high-grade varieties by infesting them with hybrids. The introduction of Egyptian cotton into the United States has introduced also the problem of Hindi cotton. There has been much speculation as to the nature and origin of this pernicious type, the name having suggested an origin from India. Experiments with Egyptian cotton in Arizona resulted in the appearance of the so-called "Hindi" variations, and comparison with other types show that Hindi cotton is of American origin. It is not identical with any of the upland varieties of the United States, but is to be associated with upland types indigenous in Mexico and Central America. Egyptian and other Sea Island types also have originated in tropical America, and the author concludes that "it becomes possible to view the Hindi variants as ex-

[11] WEEVERS, TH., Die physiologische Bedeutung einiger Glycoside. (Fortsetzung.) Recueil Trav. Bot. Néerl. **7**:1–62. 1910.

[12] COOK, O. F., Origin of the Hindi cotton. Circ. 42, Bur. Pl. Ind., U. S. Depart. Agric. pp. 12. *figs.* 2. 1909.

amples of reversion to remote ancestral characters rather than as results of recent hybridization."—J. M. C.

Comparative leaf anatomy of Agave.—In a genus consisting of species so incompletely characterized and so hard to differentiate as those of the succulents usually are, every applicable character is valuable and its application is a real service to science. Little beyond the most general and scattered facts have heretofore been recorded for the histology of Agave, and a recently published study of its leaf anatomy, by MÜLLER,[13] therefore, stands alone on the shelves. The difficulty of such a study and the value of its outcome are as largely influenced by the accuracy of naming and the representative character of the material on which it is based as on fulness of representation. In the present case the large collections of Palermo and La Mortola, where many of the species are planted out in the open, furnished material which is as likely to have been normal and accurately named as could be hoped for in the genus Agave, and its examination seems to have been carefully and systematically made. The details of structure, which are rather fully illustrated by means of drawings and low-power photographs, are followed by an analytical key occupying five quarto pages, and yet it is doubtful whether tenable names are likely to be found for many plants by its aid.—W. TRELEASE.

Death by low temperature.—Using the molds, Aspergillus, Penicillium, and Botrytis, BARTETZKO has made a new investigation under the guidance of PFEFFER, on death by cold.[14] He finds these fungi able to bear temperatures in a sub-cooled solution (without actual freezing) which would be fatal in the same time were the solution allowed to freeze. But even in the sub-cooled solution death ensues on longer exposure. With increase in the osmotic pressure of the plant sap there is a lowering of the death point, but there is no simple relation between the two. Isotonic solutions of different sorts have nearly the same effect on the resistance of the plant to cold. Only with *Aspergillus niger* did the use of a potassium nitrate solution reduce the resistance notably. In contrast to the conclusion of MOLISCH, BARTETZKO thinks death by cold cannot be due merely to withdrawal of water, because in certain cases this will be borne, while in others death takes place above the temperature at which any considerable loss of water occurs.—C. R. B.

Root excretions.—Inasmuch as the minuteness of the quantity of root excretions has again and again prevented the determination of the kind of acid, other than H_2CO_3, whose presence the corrosion experiments have led observers to

[13] MÜLLER, CARL, Beiträge zur vergleichenden Anatomie der Blätter der Gattung Agave und ihrer Verwertung für die Untersoheidung der Arten. Bot. Zeit. **67**[1]:93–139. *pls. 4, 5. figs. 22.* 1909.

[14] BARTETZKO, HUGO, Untersuchungen über das Erfrieren von Schimmelpilzen. Jahrb. Wiss. Bot. **47**:57–98. 1909.

suspect, ABERSON, in reinvestigating the question,[15] sought only to determine the concentration of the H ions to which the solvent action must be due. By using the delicate electrometric method of NERNST he has found that the concentration of the H ions corresponds to that in water (8.5 to 0.5×10^{-8} in root excretions at 16–20°, as against 7.7×10^{-8} in water at 18°). He then proceeds to show that the H ions present in such a concentrated solution of H_2CO_3 as is found in the mucus investing the root hair are from 200 to 4000 times as numerous as in the other excretions, and that the results of other observers, who used indicators, are consonant with the quantities of H ions found. The carbonic acid is quite sufficient to account for all the solvent action of the roots.—C. R. B.

Sensitizing protoplasm.—A considerable number of organisms are killed by the action of light, especially by the violet and ultra-violet rays. Among them are the small crustaceans of the genus Daphnia. Acting upon a suggestion of DREYER, HANSSEN[16] has conducted experiments to determine whether it is possible to sensitize the organism by appropriate dyes so that death would be hastened. Selecting substances that apparently do not harm the daphnias in darkness, he found that erythrosin, methylene blue, eosin, Bengal rose, and neutral red were particularly effective. He ascribes the effect to a process analogous to the sensitizing of a photographic plate to additional wave lengths, so that the added energy absorbed produces the desired effect more quickly than without the sensitizer. The paper adds strength to the theory that chlorophyll acts as an optical sensitizer in photosynthesis.—C. R. B.

Vascular anatomy of ferns.—PELOURDE[17] proposes to classify the vascular structures of the petioles of recent and fossil ferns by arranging them in four groups: (1) with a pair of vascular bundles, each having the form of a "hippocampus," which may nearly or quite meet on the lower (abaxial) side, forming a horseshoe; (2) with several bundles arranged as in the first class, each of the two adaxial bundles showing a crook which corresponds to the head of the hippocampus; (3) with a single arc-shaped strand, open above; (4) similar to the last but open below and closed above. No mention is made of the extensive memoir of BERTRAND and CORNAILLE,[18] who consider that type (3), found in Osmunda, represents the primitive condition from which all the others may be derived.—M. A. CHRYSLER.

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[15] ABERSON, J. H., Ein Beitrag zur Kenntnis der Wurzelausscheidungen. Jahrb. Wiss. Bot. **47**:41–56. 1909.

[16] HANSSEN, OLAV, Recherches experimentales sur la sensibilisation optique du protoplasma. Overs. Kgl. Danske Vidensk. Selsk. Forh. **1908**:113–132. *pls. 4.*

[17] PELOURDE, F., Recherches comparatives sur la structure des fougères fossiles et vivantes. Ann. Sci. Nat. Bot. IX. **10**:115–147. *figs. 32.* 1909.

[18] BERTRAND, C. EG., ET CORNAILLE, F., La masse libéroligneuse élémentaire des filicinées actuelles et ses principaux modes d'agencement dans la fronde. Trav. et Mém. Univ. Lille **10**:1–221. 1902.